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ASTRONOMY

December 1986
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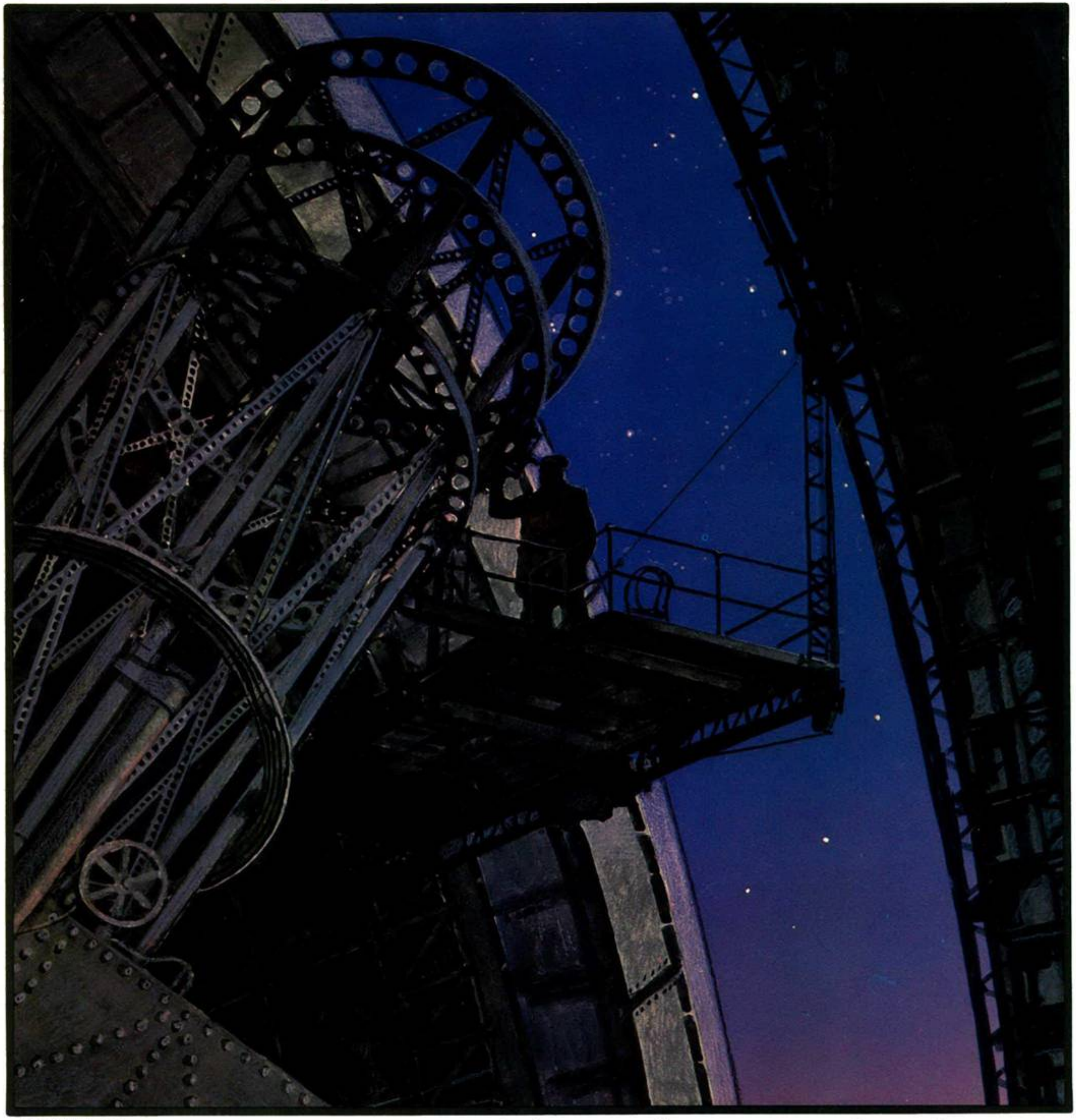
Mount Wilson: The Observatory

Understanding Celestial Angles

How to Photograph Dark Nebulae

ICD# 08070



A Night on the 100-Inch Telescope

MEADE SUPER WIDE ANG
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Super Plössls

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Air-Spaced Barlows

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Design Specifications: Meade Series 4000 eyepieces yield the widest possible fields of view, consistent with pinpoint edge-of-field sharpness and long eye relief, and yet with extremely low astigmatism, spherical aberration, and off-axis color. Incorporating 7-layer multicoatings and edge-blackened optics for optimal image contrast, these sophisticated 5- to 8-element designs permit levels of optical corrections virtually impossible to achieve with eyepieces of fewer elements. The polished chromed-brass barrels are threaded for standard filters, and, where practical (see table), eyepieces and both Barlow lenses are parfocal, allowing eyepiece interchangeability without refocusing.

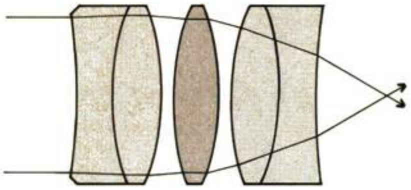
Eyepiece Groups: Eighteen focal lengths in the three Series 4000 eyepiece groups permit precisely the right eyepiece for any application. Whether your telescope is an f/4 Newtonian, an f/10 Schmidt-Cassegrain, or an f/16 refractor, its performance will benefit by using these incredible oculars:

Super Plössls: With 5 optical elements rather than the traditional 4, Meade Super Plössls provide a 40% improvement in corrections for chromatic aberration and edge-distortions over any other premium Plössls. Best for general observing at moderate cost, the Super Plössl eyepieces are perfect optical complements for the Series 4000 air-spaced Barlows, below. Try the 56mm on your 8" Schmidt-Cassegrain for an actual field of over 1.4° at 36X!

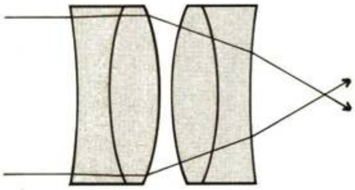
Super Wide Angles: These 6-element eyepieces, with their 67° fields, offer exquisite wide-angle images at low to medium powers, ideal for star fields, galaxies, and other deep-space phenomena. Focal lengths with 1¼" barrels yield extremely high-resolution, high-power lunar and planetary images when combined with one of the Series 4000 Barlows.

Ultra Wide Angles: The ultimate in modern eyepieces, Meade 8-element Ultra Wide Angles permit extreme image fidelity and sharpness over an amazing 84° apparent field: for moderate to high power applications, no other eyepieces come close. A magnificent optical match with Schmidt-Cassegrains and fast Newtonians.

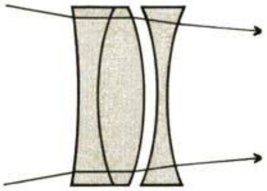
Series 4000 Barlow Lenses: The most sophisticated Barlows ever developed for commercial telescopes, these 2X and 2.8X Telenegative Amplifiers include 3-element, air-spaced, multi-coated optics, unmatched in image resolution and color correction. Both models optically complement the Series 4000 eyepieces, while significantly enhancing the performance of other eyepieces as well.



Meade 5-element Super Plössl design: the central lens element enables significant reductions in chromatic aberration and edge-distortions over other premium Plössl designs.



Other premium Plössls: include only the traditional 4-elements.



Meade Series 4000 Barlows: 3 elements, air-spaced, instead of the standard 2 non-air-spaced elements.

Series 4000 Eyepieces and Barlows

Super Plössls (5-elements)	APPARENT FIELD	BARREL DIA.	PARFOCAL
6.4mm	52°	1¼"	Yes
9.7mm	52°	1¼"	Yes
12.4mm	52°	1¼"	Yes
15mm	52°	1¼"	Yes
20mm	52°	1¼"	Yes
26mm	52°	1¼"	Yes
32mm	52°	1¼"	Yes
40mm	44°	1¼"	No
56mm	52°	2"	No
Super Wide Angles (6-elements)			
13.8mm	67°	1¼"	Yes
18mm	67°	1¼"	Yes
24.5mm	67°	1¼"	Yes
32mm	67°	2"	No
40mm	67°	2"	No
Ultra Wide Angles (8-elements)			
4.7mm	84°	1¼"	Yes
6.7mm	84°	1¼"	Yes
8.8mm	84°	1¼" & 2"	Yes
14mm	84°	1¼" & 2"	No
Barlow Lenses (3-elements, air-spaced)			
#140 2X Telenegative Amplifier		1¼"	Yes
#142 2.8X Telenegative Amplifier		1¼"	Yes

Meade 2" Mirror Diagonal: For attachment to Schmidt-Cassegrain telescopes, the 2" Mirror Diagonal permits use of Series 4000 eyepieces with 2" barrels. The 1/10-wave-flat Pyrex mirror, manufactured at the Meade Costa Mesa optical facility, is multicoated with enhanced aluminum for maximum reflectance. An adapter for 1¼" eyepieces is included.

Where To Buy: Meade Series 4000 eyepieces and Barlows are available from over 600 authorized Meade dealers in the U.S.A. and Canada. Call us toll-free (see below) for your nearest dealer.

Prices: Notwithstanding their performance standards and optical sophistication, Meade Series 4000 eyepieces and Barlows are priced very competitively with other premium oculars and Barlows.

Warranty: All Series 4000 systems are covered by the Meade Limited Lifetime Warranty—the most extensive in the industry. See the Meade catalog for details.

New 1986 Meade General Catalog 86-C: $3.00

Just-published, the new Meade 1986 General Catalog includes complete information on the full range of Meade astronomical products, along with a supplement on **"How To Choose Your Eyepieces."** Send $3.00 for your copy.

U.S. and Canada Dealer Locations & Assistance

For your nearest Meade dealer location, or for free telescope information and assistance, call Meade Instruments **toll-free** from anywhere in the continental U.S.A., (except Calif.):

1-800-854-7485

From all other areas, including California, call direct: **(714) 556-2291**

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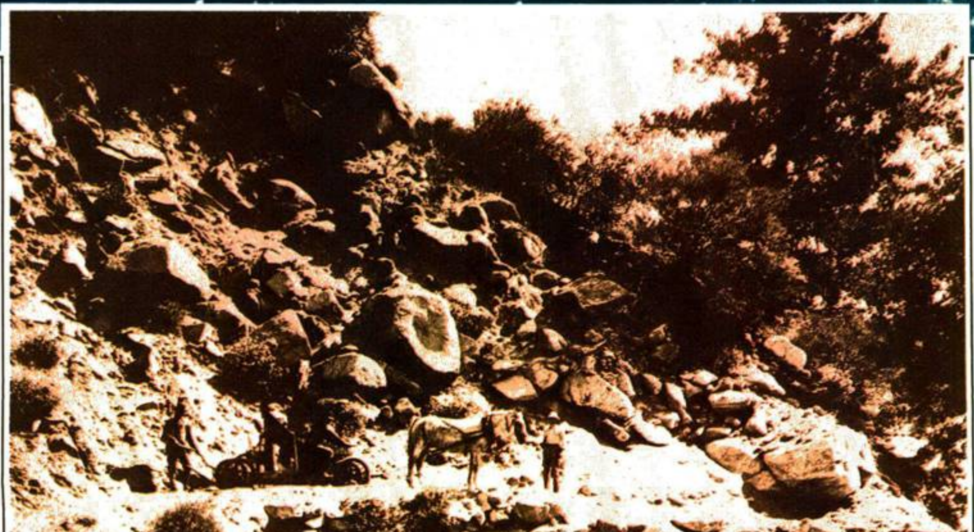

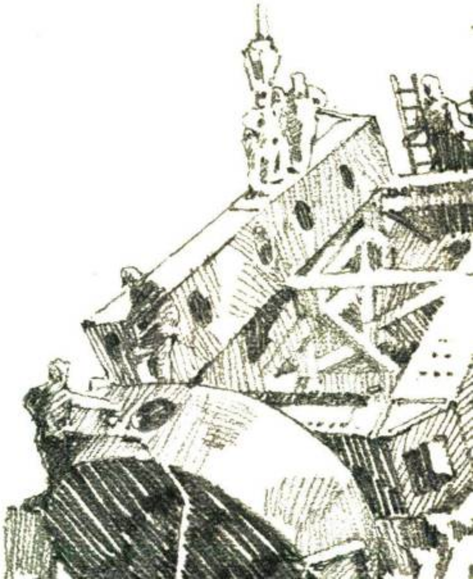

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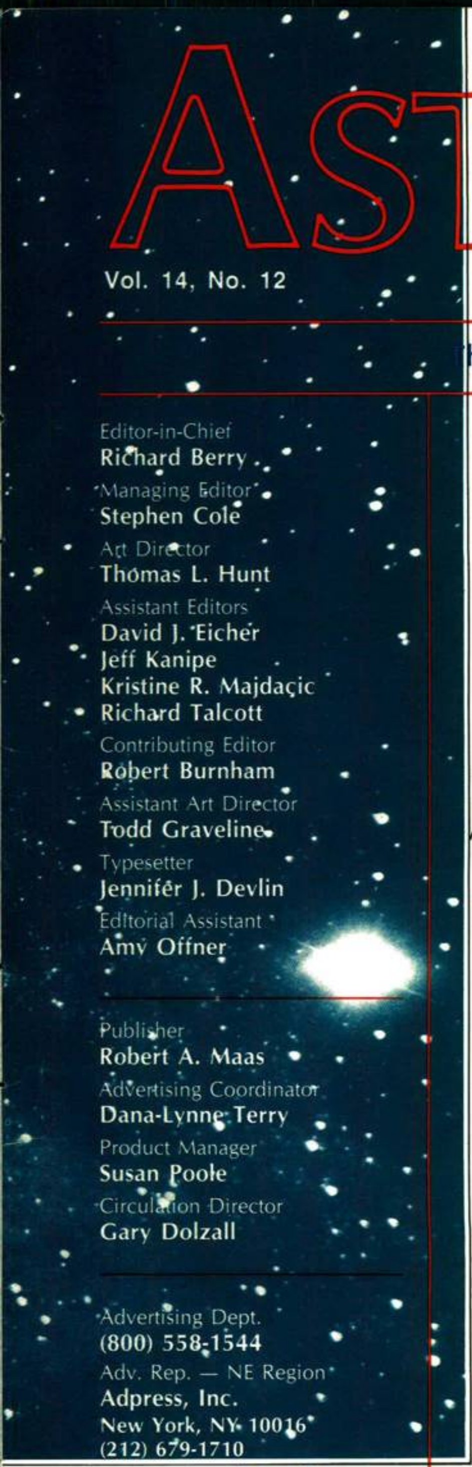

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Cover: The year is 1923; the telescope is the largest in the world. In the chill mountain air an astronomer exposes a plate at the Newtonian focus of the 100-inch Hooker reflector atop Mount Wilson, hoping to record the images of faint variable stars that will yield the distance to the mighty spiral galaxy in Andromeda. Painting by Bruce Bond. These pages: This month ASTRONOMY tells the story of the genesis of the big reflector atop Mount Wilson.

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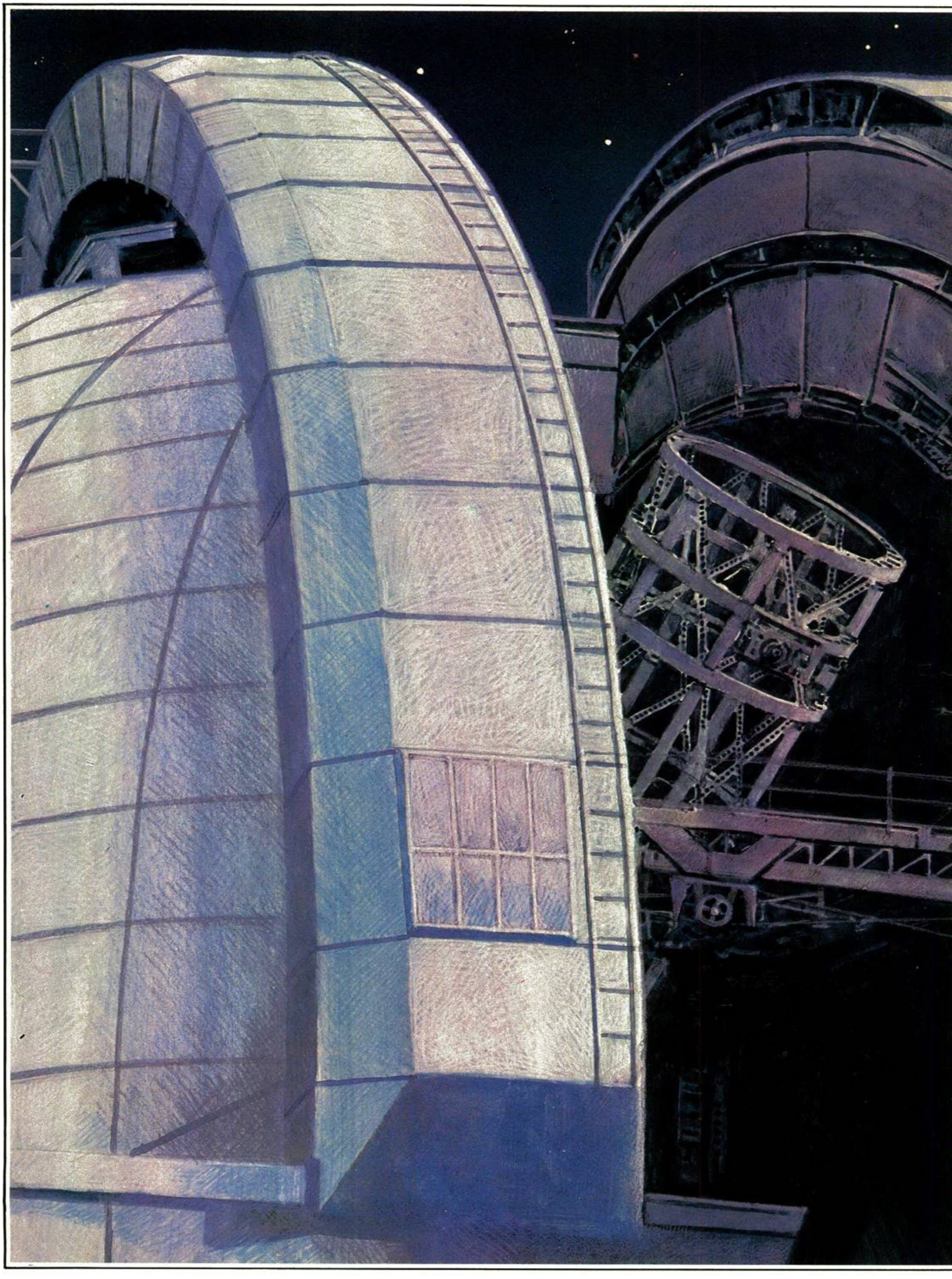
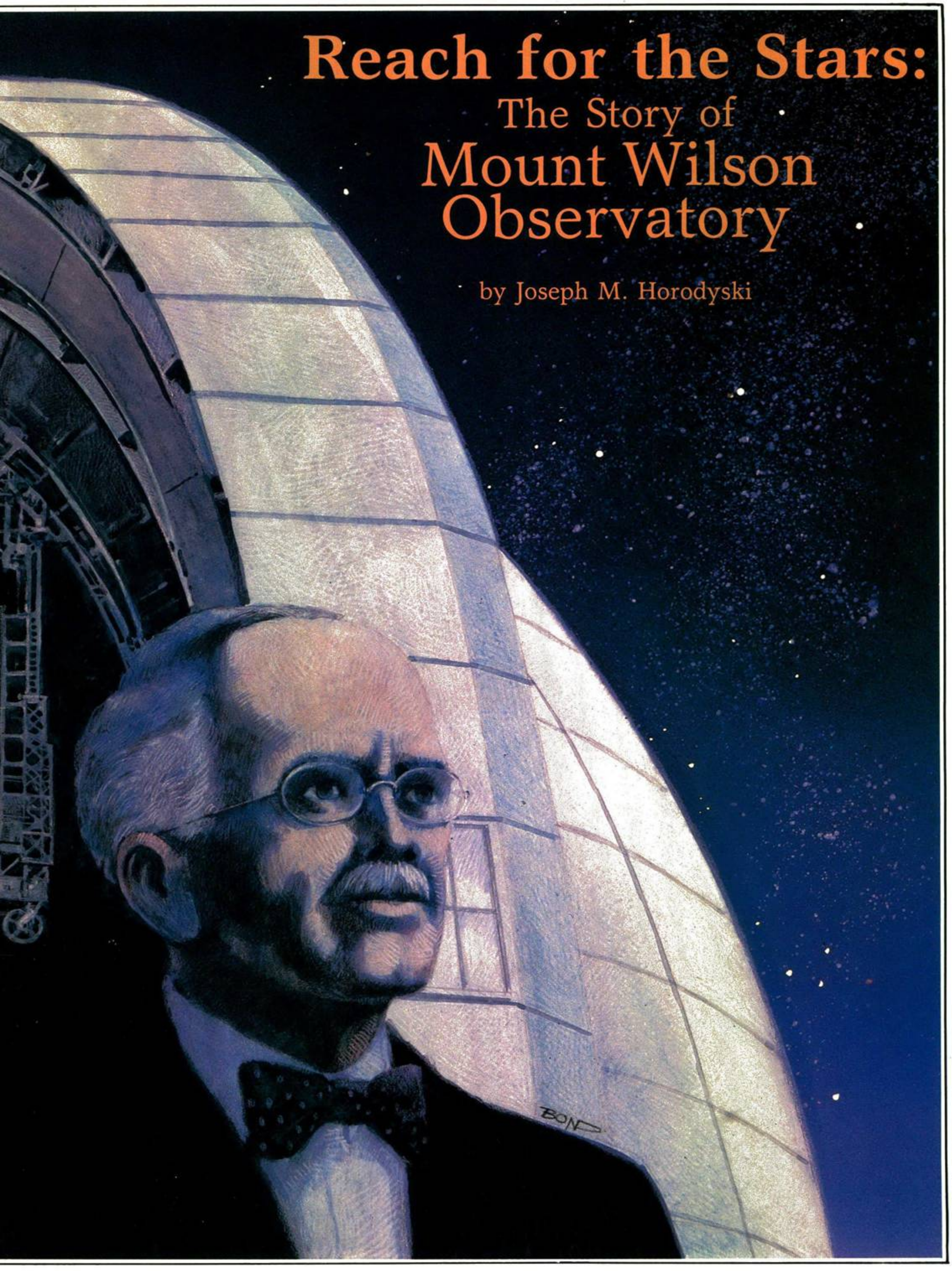


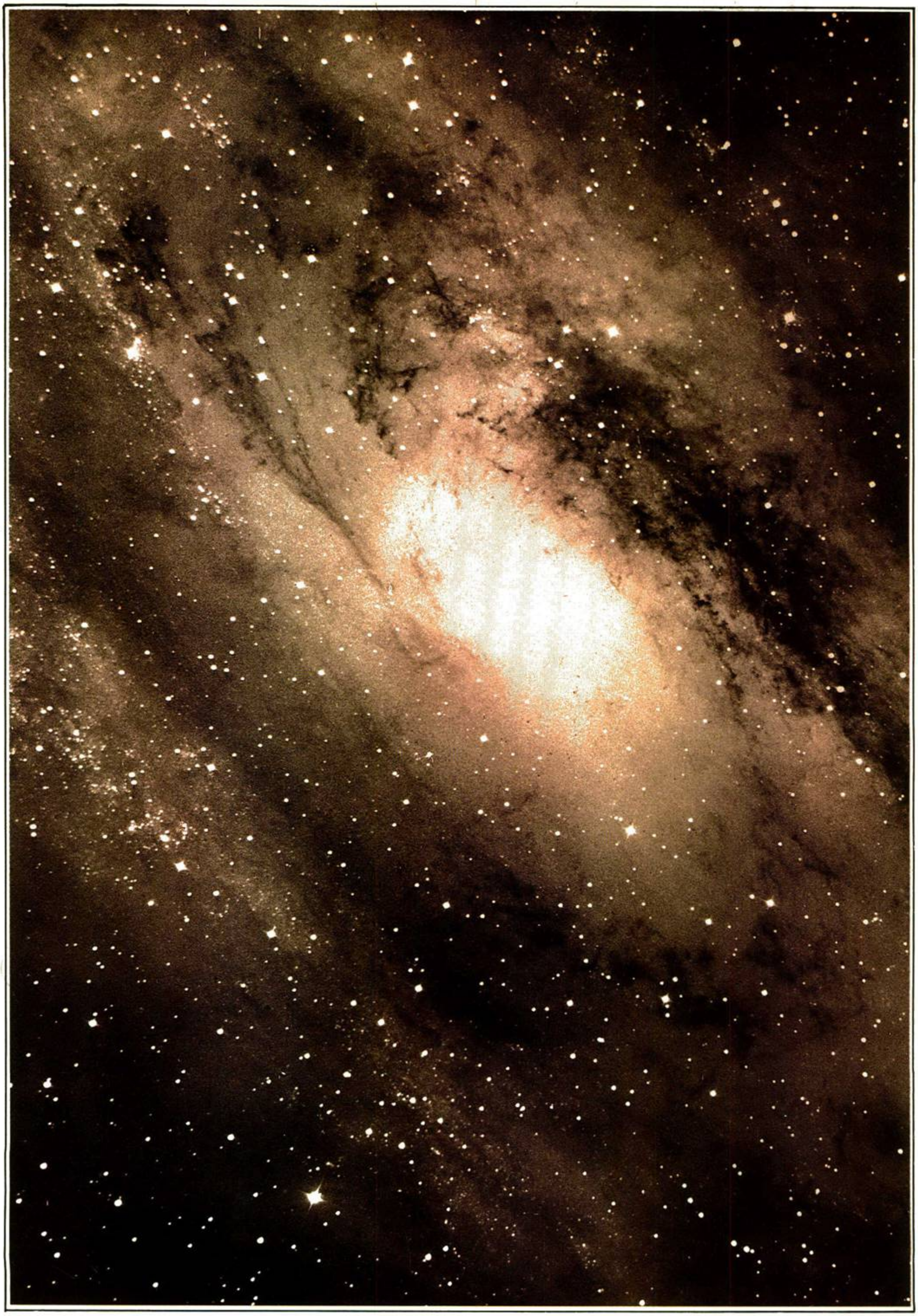
Reach for the Stars:

The Story of Mount Wilson Observatory

by Joseph M. Horodyski



Art by Bruce Bond



In the summer of 1985, a literal giant in the field of astronomical telescopes and a star in its own right passed into the annals of history. On July 1, 1985, the 100-inch telescope of the Mount Wilson Observatory was "moth-balled." The observatory, perched in the San Gabriel mountains overlooking Los Angeles, had been fighting a losing battle with light pollution. Funding for the observatory, provided since the observatory's founding by the Carnegie Institution of Washington, has been, in effect, diverted to the Las Campanas Observatory in Chile, where high altitudes, dark skies, and long observing periods will enable the astronomers to continue astronomical investigations begun decades ago with the 100-inch telescope.

As noteworthy as its passing, however, were the telescope's remarkable beginnings, filled with all the drama and suspense of a good adventure novel. "Wilson's Peak" (or "Signal Point" as it was known by the old-timers who customarily lit signal flares to announce their arrival at the summit) had long been a favorite location for hikers and tourists to camp when George Ellery Hale arrived in Pasadena, California, on a warm summer's day in 1903. He was scouting the area for a suitable location to build a new and independent solar observatory — a dream of his for five years.

A year before Hale had read in a newspaper of philanthropist Andrew Carnegie's decision to donate $10 million for the founding of the Carnegie Institution. Carnegie stipulated that the grant was to be used for "the encouragement in the broadest and most liberal manner for investigation, research and discovery in the field of science; and the application of this knowledge for the improvement of mankind." Dr. Daniel Gilman, who was appointed director of the Institution, organized it into five separate sections dealing with the sciences, the last section being devoted to astronomy.

Hale saw this as an opportunity to obtain the funds he needed. He quickly contacted Dr. Gilman with his proposal. Gilman was sufficiently impressed to invite Hale to serve on the Advisory Committee on Astronomy, which had been formed to advise the Executive Committee of the Institution on astronomical matters. Hale soon became a driving force behind the plans to build a small solar observatory in southern California and arranged to have $5,000 appropriated to make a study of possible sites.

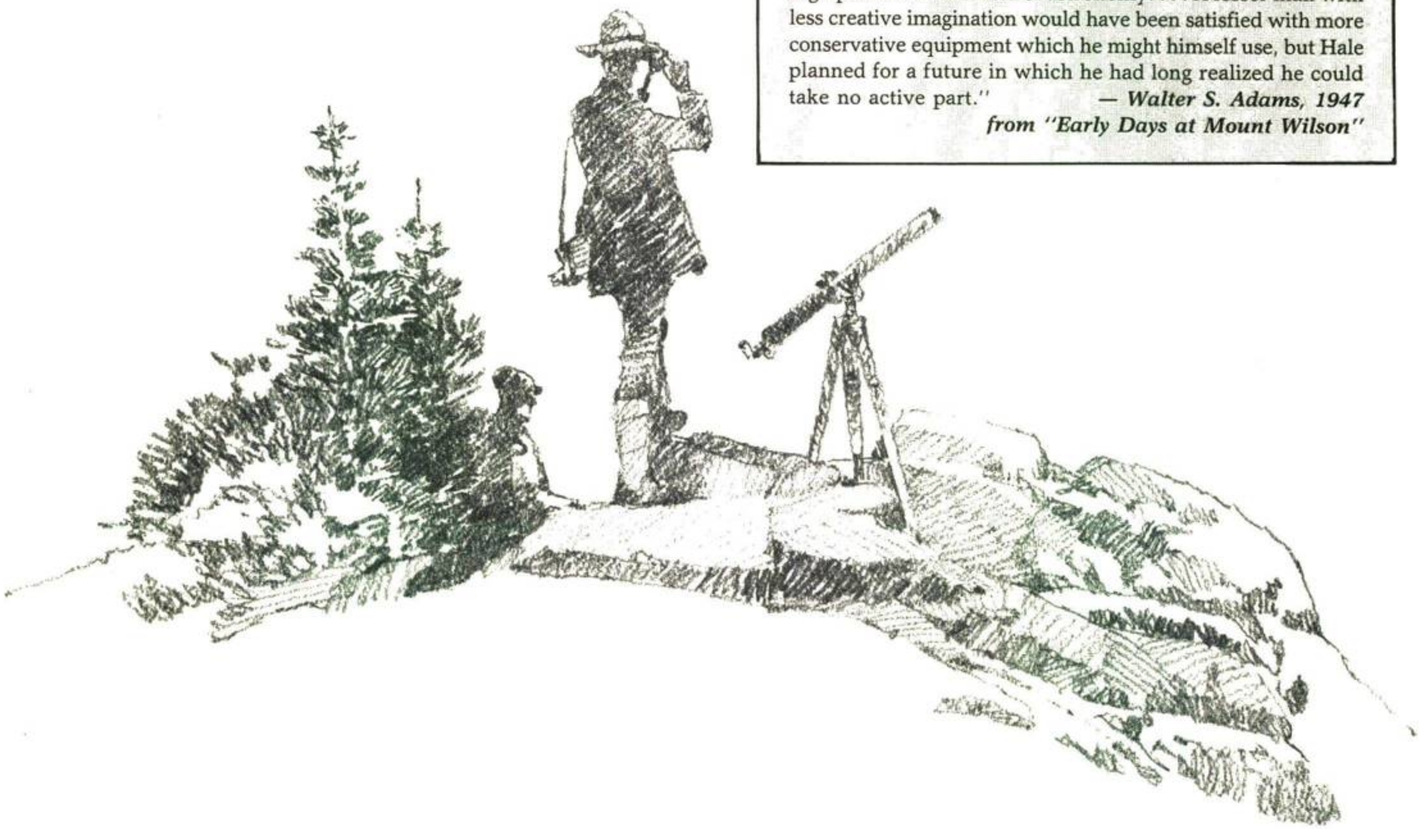
Thus it was that W. J. Hussey of the Lick Observatory dutifully set out with his own 9-inch refractor to try out candidate sites firsthand. Hussey found two locations he considered exceptional — Mount Wilson and Palomar Mountain — both near Los Angeles. Although Hussey preferred Palomar Mountain because of its climate and isolation from the city,

The 100-inch Hooker telescope revealed the universe in more detail than ever seen before. Before the telescope was built, nobody really knew whether the spiral nebulae strewn across the sky lay inside our galaxy and were stars in formation, or whether they were distant "island universes," galaxies like our own. Within a few years of its completion, the 100-inch turned up the decisive clues.

Mr. Hale Explores Mt. Wilson

"...I am impressed more and more by the greatness of the figure of Hale, without whom it is doubtful whether the Observatory, if established at all, could ever have attained its high position in the field of astronomy. . . . A lesser man with less creative imagination would have been satisfied with more conservative equipment which he might himself use, but Hale planned for a future in which he had long realized he could take no active part."

— Walter S. Adams, 1947
from "Early Days at Mount Wilson"



the difficulty in transporting the major elements of an observatory and telescope up the steep mountainside, and the advantage of an existing railway line near the foot of Mount Wilson, led him to recommend Mount Wilson. Palomar would wait a while longer for its destiny.

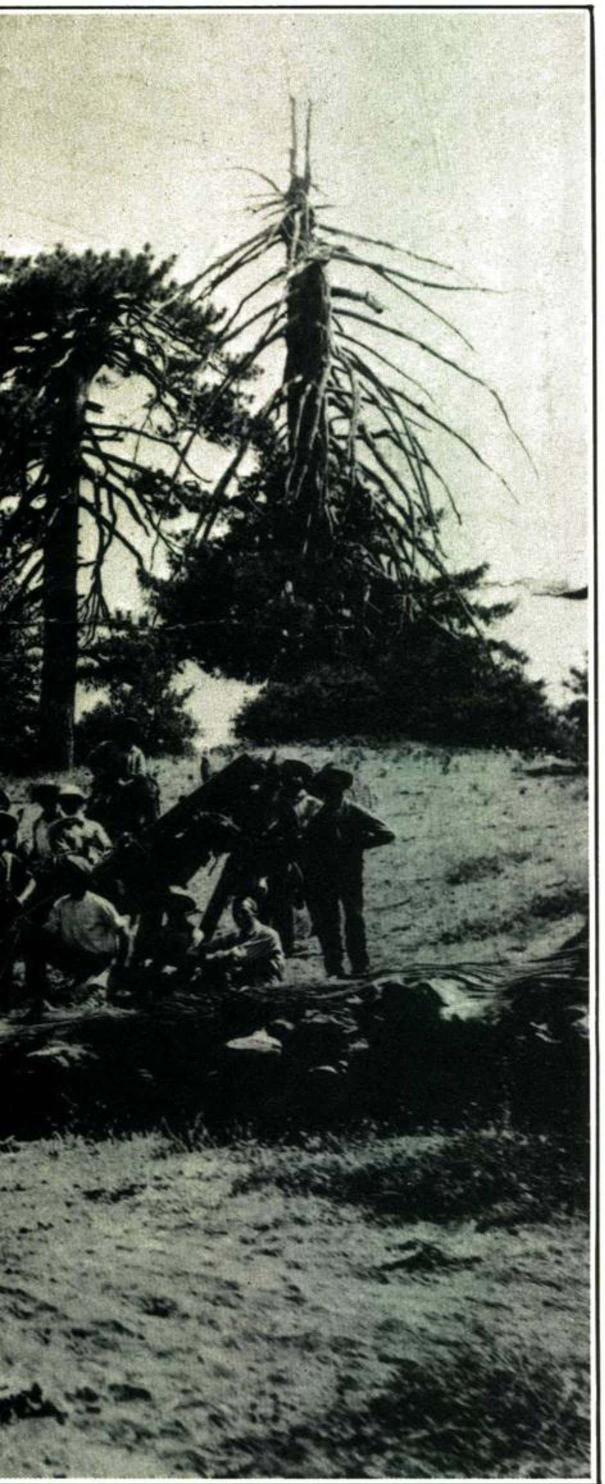
Meanwhile, Hale was hatching bigger plans. Andrew Carnegie was an enthusiastic supporter of science and had privately told Hale that he would be interested in funding a major observatory if the scientific results could justify the expenditure. Hale soon proposed that the Carnegie Institution fund an astronomical observatory with a 60-inch reflector atop Mount Wilson.

In June 1903, Hale arrived with the members of his family and, after settling them in the bustling town of Pasadena at the foot of the mountains, set out to scale Mount Wilson and see the site himself. A few weeks of observations with a 3-inch refractor convinced him

Mount Wilson Observatory was built with the sweat of mules and men. The original caption reads: "Laborers and animals employed on Observatory construction on Mt. Wilson, during July and August 1904."

that he needed an instrument of greater power. When he returned to the east coast, Hale was convinced that Mount Wilson was the best possible site for his observatory.

Time passed, and Carnegie Institution committees met and discussed funding for the many projects that had been proposed in a wide variety of scientific disciplines. Hale anxiously awaited word that the funds for the observatory had been approved, and the Carnegie Institution's decision not to go forward with the project bitterly disappointed him. With characteristic determination, however, he decided to make solar observations from Mount Wilson on his own initiative. In December 1903, Hale returned to California.



Hale's solar work proved successful and soon took on a momentum of its own. He even persuaded John D. Hooker, a wealthy Los Angeles businessman and personal friend, to donate $1,000 to finance the shipment of a 10-inch photographic telescope from Yerkes for the completion of the southern plates of a photographic atlas of the Milky Way that E. E. Barnard was then preparing.

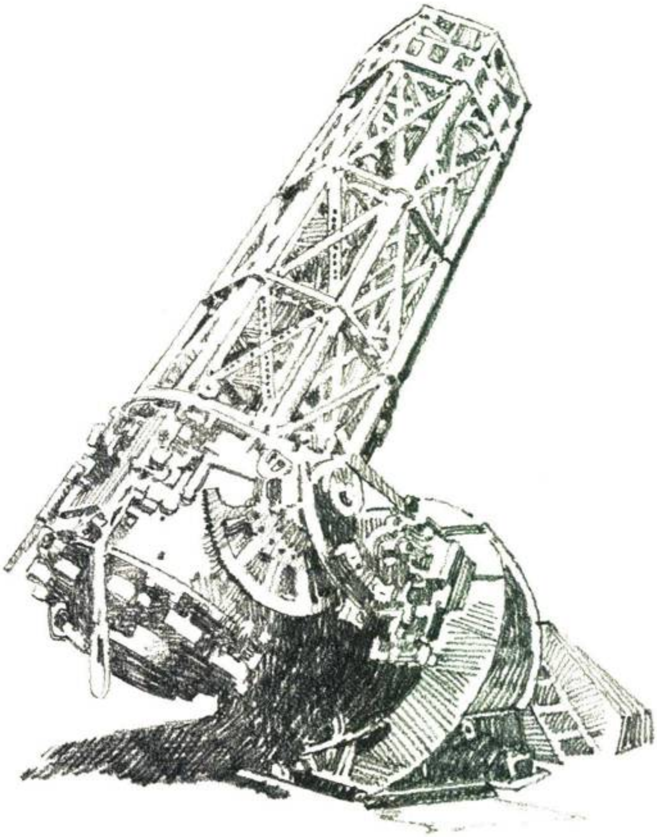
In the early part of the century only two narrow trails made their way to the top of the mountain, and these dated from as far back as 1864. All of Hale's equipment and supplies had to be brought up by mule, and it wasn't long before Hale was dreaming of a permanent establishment at the site instead of the renovated log cabin he was using.

Hale and his assistant, George D. Jones, spent the winter of 1903 alone on the summit making solar observations; Hale later said the time he spent there was "the most novel, interesting, and enjoyable part of [my] life." Under the bright sunshine and the quiet and

The 60-Inch Telescope

"An important piece of work during the summer was the construction of a permanent metal screen to the exterior of the 60-inch telescope dome to replace the canvas used hitherto. On account of heavy snow and wind storms we have not found it possible to leave the canvas screen on the dome throughout the winter, and in its absence the air inside the dome (on clear days) becomes considerably heated on account of the direct exposure of the metal roof to the sun's heat."

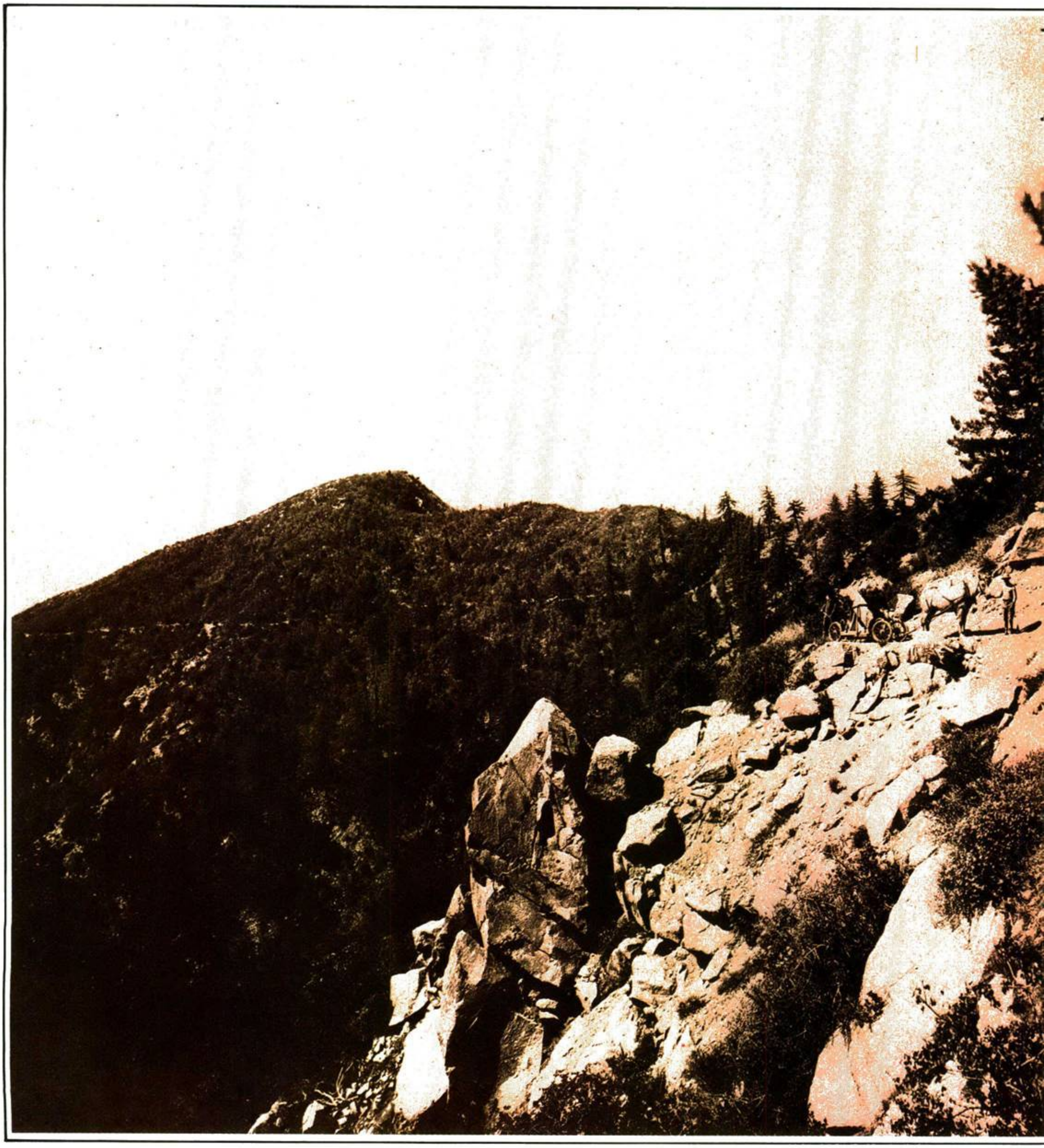
— ***George Ellery Hale, 1912***



beauty of the surrounding mountains, Hale's depression over the Institution's failure to approve the new observatory quickly vanished.

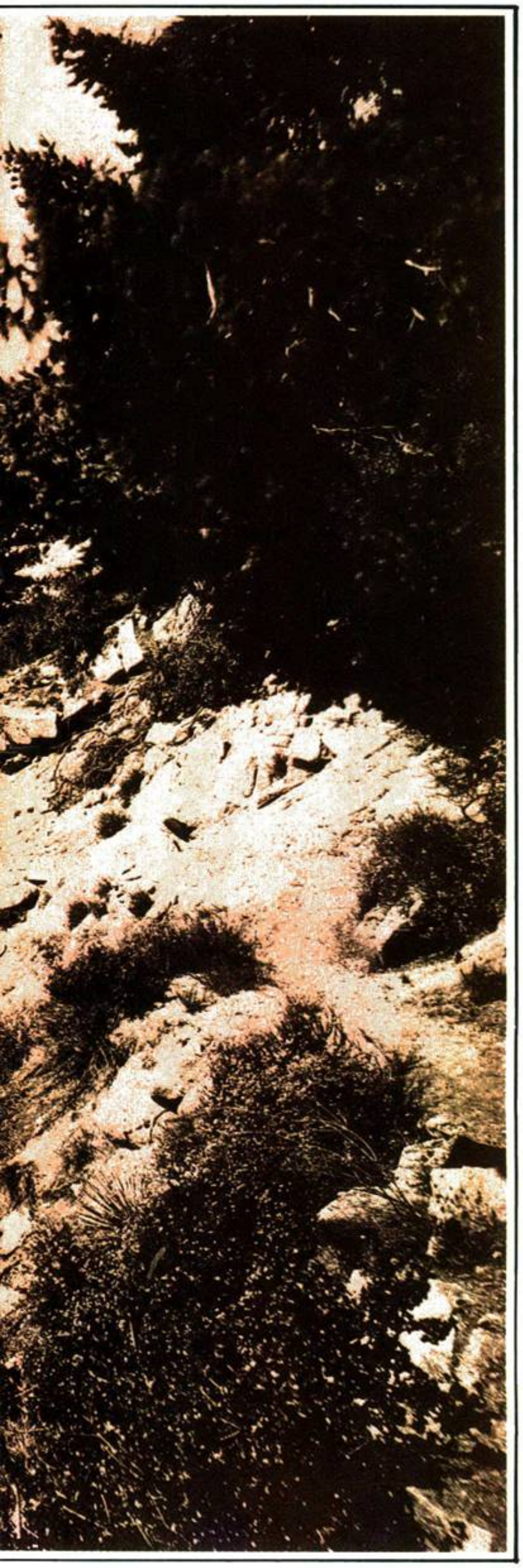
In 1904, armed with the solar photographs he and a colleague had taken, Hale set out to attend a meeting of the National Academy of Sciences in Washington, hoping this time to persuade the Carnegie Institution of the need for an observatory at Mount Wilson.

This time his proposals were received favorably. The Carnegie Institution made Hale a grant of $10,000 to continue his work on Mount Wilson, with a promise of additional funds if needed. He eagerly returned to Pasadena to oversee the placement of additional tele-



Access to Mount Wilson was not easy. The rugged trail was only three feet wide in places. The original caption reads: "Automobile truck on the way to Mt. Wilson, showing trail on side of farther mountain."

scopes on the summit in 1904, and personally designed a new building to house them, a small electrical plant for power and lighting, and an adequate water supply. By the time the appropriated funds had been used up, Hale had once more returned to Washington to lobby again for the establishment of a permanent 60-inch reflector which, in that day and age, would be the largest telescope in the world. Four solar telescopes were already in operation on Mount Wilson and Hale felt sure their success would convince the trustees of the Institution of the value of Mount Wilson as an observing site.



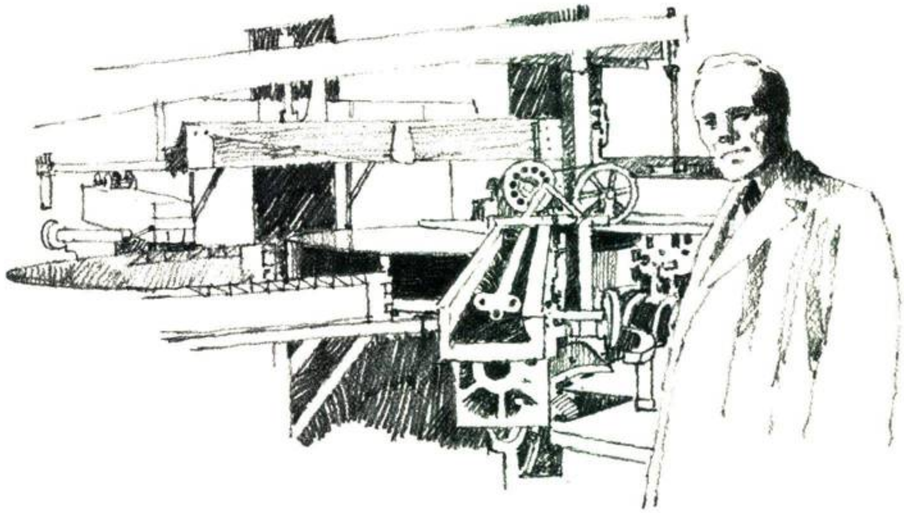
Hale returned to Pasadena two weeks later expecting word of the Institution's decision to be waiting for him — there was none. Nervously anxious should the Institution again turn him down, Hale had started up the narrow nine-mile trail that led to Mount Wilson from Pasadena when a messenger caught up with him and informed Hale that the Institution had just telephoned its approval, granting him $300,000 in funds over the next two years, and authorizing him to proceed with the work. George Ellery Hale's dream was about to be transformed into reality.

Hale attacked the problem of building the new observatory with energy and ingenuity. For the telescope itself he proposed a shortcut. William Hale, George Ellery Hale's father and a successful businessman, had commissioned the making of a 60-inch mirror in 1897, but the big disk of glass lay in storage for years

Grinding the 100-Inch

"The work of parabolizing the 100-inch mirror has been brought by Mr. Ritchey to successful completion. For many months, as the figure was gradually brought nearer to a true paraboloid, daily optical tests were made both at the center of curvature and at the primary focus. The focal tests involved the use of the 60-inch plane mirror which was made here for this purpose, and the close agreement and consistency of the daily results secured by the two methods gave much satisfaction and confidence in the outcome."

— ***George Ellery Hale, 1916***



for lack of funds to complete the telescope. Now that a suitable site was in preparation, the elder Hale was happy to donate the mirror to the Mount Wilson project. The immediate availability of the glass disk cut years off the project.

While Hale turned his attention to the construction of a new optical and instrument shop, the work of designing the mounting and dome began. Hale conferred often with members of his staff, incorporating their suggestions into the plans. As the planning drew to a close, contracts were let for the iron and steel work.

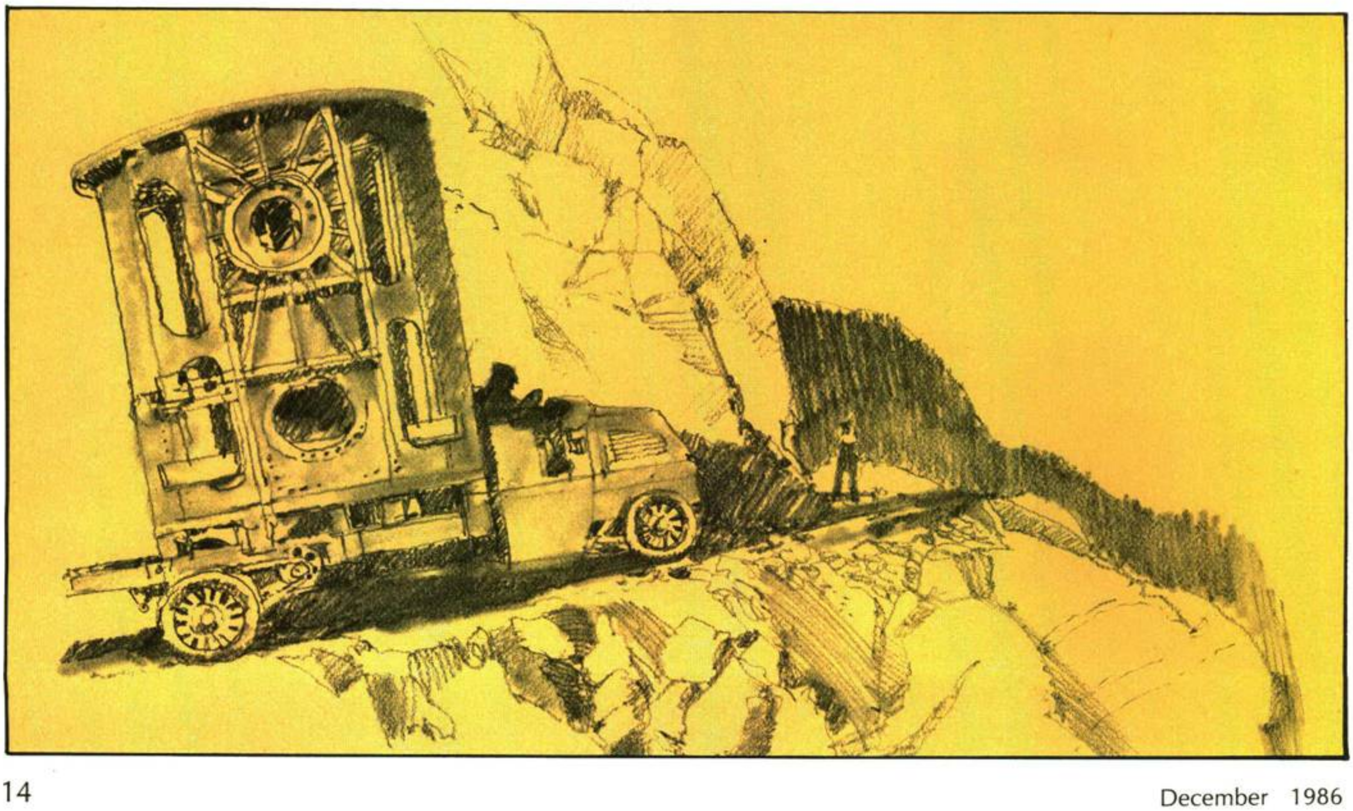
Transporting the many tons of iron, steelwork, and hundreds of tons of concrete up a three-foot-wide trail presented Hale with another problem. After considering — and discarding — a variety of solutions, Hale finally decided, at his own cost, to widen the trail into a one-way road so that the larger pieces of equipment could be brought up by truck.

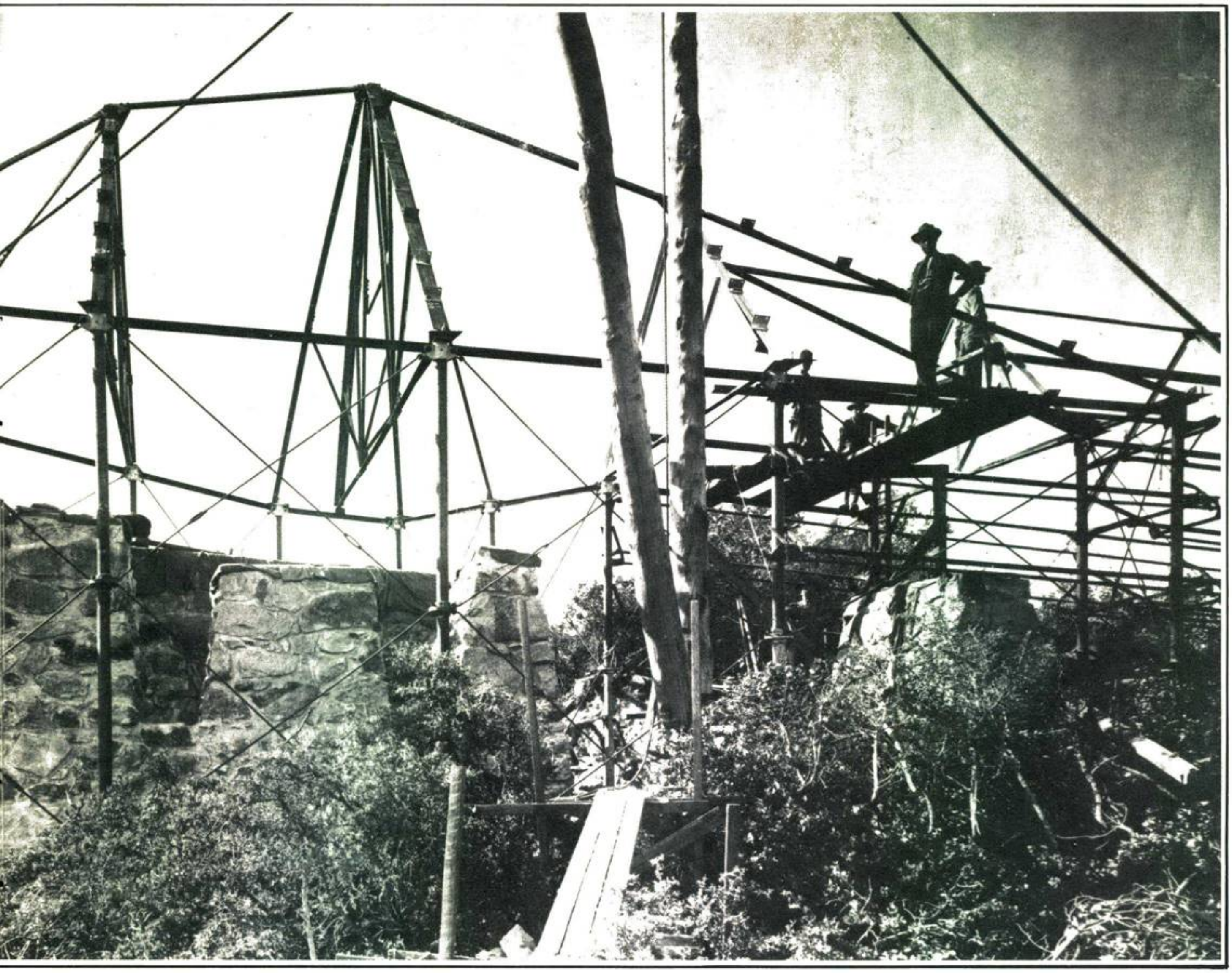
It was well into 1908 before the mirror, mounting, and dome were completed and ready to be hauled to the mountaintop. A combination of mule-power and

Hauling Parts up the Mountain

"Notwithstanding the loss of the 3-ton truck by accident, this means of transportation has proved efficient and expeditious. The 1-ton truck has made daily trips with supplies and members of the staff. . . . A new 3-ton Mack truck, of the same make and type as the old one but better adapted to our purposes, has been purchased and was in daily operation during the construction season on the mountain. With it about 275 tons of material, mainly for the 100-inch telescope, the reconstructed 60-foot tower telescope, and the 10- and 6-inch telescopes, have been hauled to the summit.

— ***George Ellery Hale, 1914***





Solar observing was dear to George Ellery Hale's heart, so much so that the first instruments built on Mount Wilson were solar telescopes. The caption reads: "Iron construction of telescope building on Mt. Wilson. East side, showing solar spectroscope pier."

gasoline-powered trucks dragged the heavy telescope assemblies up the steep mountainside. They arrived without accident and the instrument was in place by year's end, ready for use. Hale and the astronomers at the observatory immediately began to study the spectra of distant stars; from these investigations he hoped to formulate a theory of stellar evolution.

While these activities were going on, the germ of the Mount Wilson complex was in the making. John D. Hooker, the local businessman who had supported Hale when the Institution had originally turned down Hale's proposals, became intrigued with the possibility of constructing an even larger instrument. At first Hooker suggested an 84-inch-diameter mirror, and when Hale concurred that such a size was technically feasible, Hooker proposed a still larger telescope, one with a mirror 100 inches across.

At the time of Hooker's offer, the 60-inch was the largest telescope in the world and would surely remain so for another decade, since there were no other initiatives anywhere in the world to build such a large telescope. The difficulties involved in the design, construction, and transportation of the 60-inch had been enormous. Was a 100-inch telescope even possible? No one knew. But Hale was captivated by the idea and, despite many unknown factors, believed that once such a project was started, problems could be solved as they came up. Hooker was willing to take the chance and advanced $45,000 to Hale to start work on the great mirror. The contract for the new mirror was awarded to the French Plate Glass Company of St. Gobain, France, the same firm that had produced the excellent mirror for the 60-inch telescope.

As might be expected, the project soon ran into difficulties. When the 5-ton glass casting cooled, numerous air bubbles were detected in its structure. The bubbles had formed between the layers of molten glass as it was poured into the mold. After some initial tests, experts at the French Plate Glass Company pronounced it a failure. Two more disks were cast, but neither was as good as the first.

Hale was less daunted than the experts. He didn't think air bubbles would interfere with the operation of the mirror and asked that the first mirror be shipped anyway. Upon its arrival at Pasadena, Hale and his optics expert, George Willis Ritchey, examined the disk closely. They decided not to use it because Ritchey feared that its surface would expand and contract unevenly with every temperature change due to the air bubbles. What was destined as the primary mirror for the world's largest telescope thus lay unwanted and unused for more than a year in the observatory's optical shop. During that time Hooker passed away, enthusiastic about the 100-inch telescope despite its difficulties.

But Hale could not put the 100-inch out of his mind, for he still had lingering doubts that Ritchey was wrong and that the glass disk might prove usable. To put his mind to rest, Hale sought out the greatest American authority on glass and optics, Dr. Arthur L. Day of the Carnegie Institution. Day traveled to Pasadena to see the disk and, after a critical examination of the mirror, came to the conclusion that rather than making the glass defective, the bubbles would prevent the surface from distorting. Hale, with his usual optimism, believed Day, but Ritchey remained pessimistic and maintained that the finished mirror would be unable to retain a good figure. Hale gave the go-ahead to proceed with the work, and Ritchey and his assistants began the long and arduous task of grinding and polishing the mirror. It would be nearly six years before the delicate surface was completed.

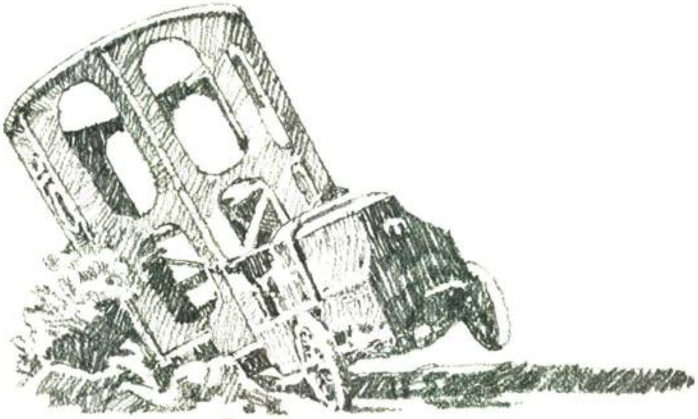
In the meantime Hale began arranging the financing for the mounting and a dome to house the great 100-inch telescope. As in the case of the 60-inch, he was successful. In early 1910, Andrew Carnegie himself visited the Mount Wilson site to inspect the work underway there; what he saw, along with George Hale's devotion to the project, impressed him enough to allocate Hale an additional $500,000 to carry the task to completion.

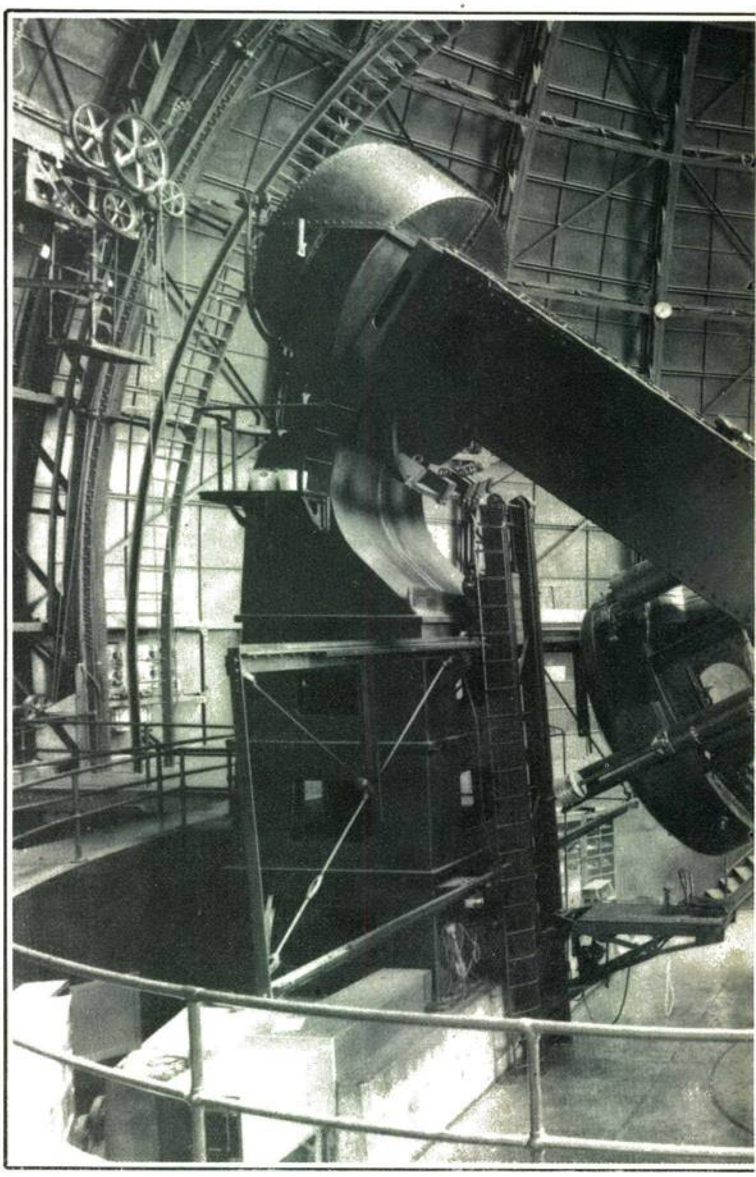
This task was interrupted, however, by World War I. The manufacture of many of the larger parts of the mounting had to take second place in many factories to the production of war material. Ritchey finished preparing the mirror and declared it to be as near perfection as the hand of man could make it. Still pessimistic, however, he warned that only actual observations would indicate what the big mirror's behavior would be.

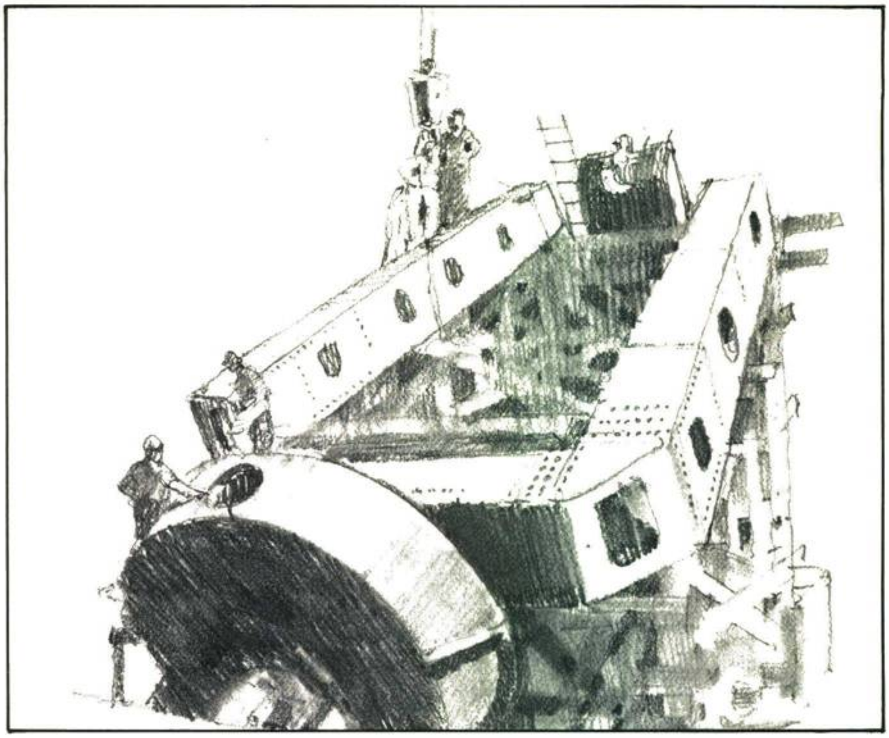
The long-awaited moment of truth came in November 1917 when the massive telescope was turned toward the night sky for the first time. Alfred Noyes, the English poet, happened to be visiting California at this time; Hale invited him to be present at the occasion. Together with Hale's chief assistant, Walter

Erecting the Telescope's Mounting

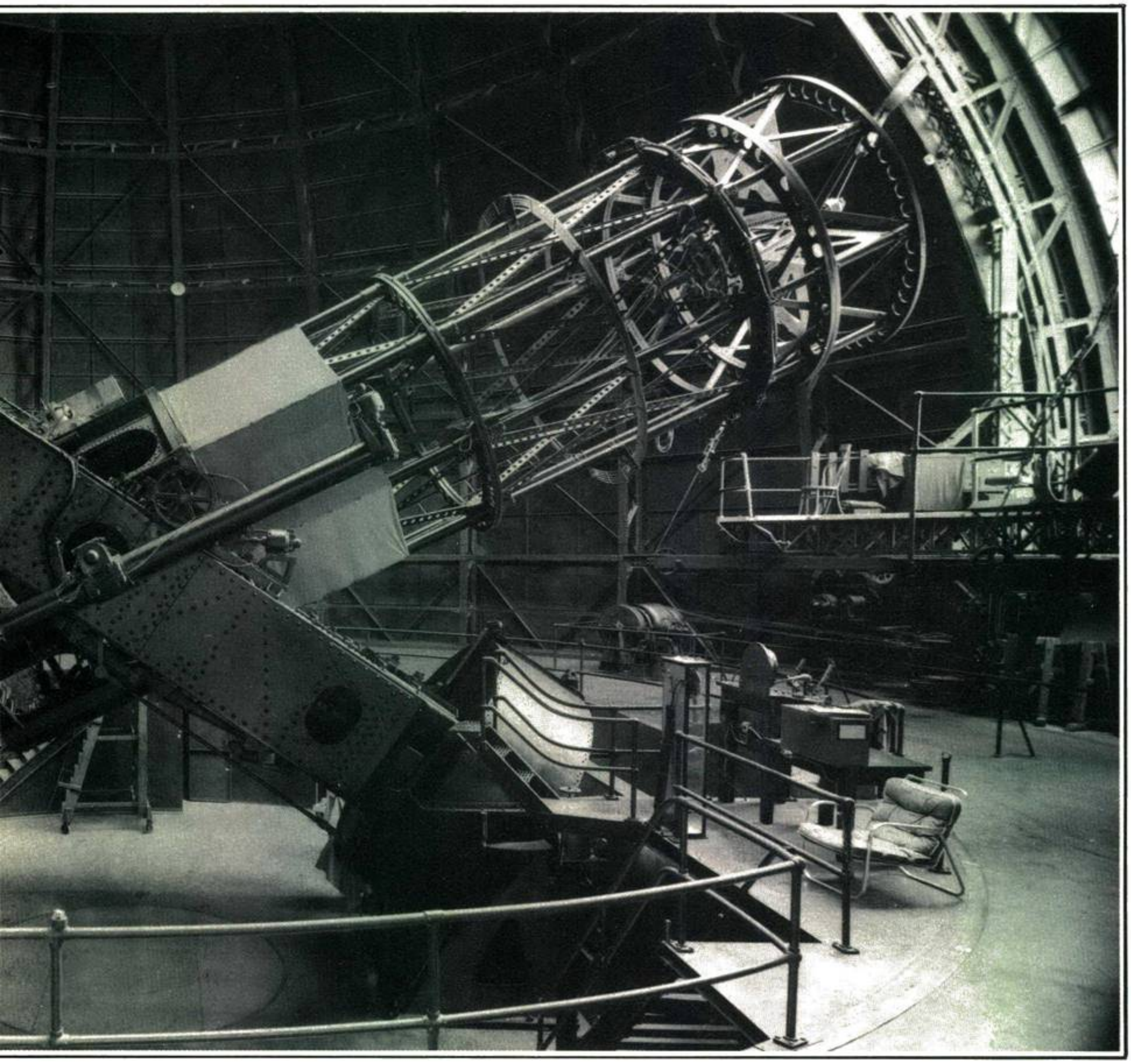
"In the Pasadena shop the work on the smaller parts of the mounting has proceeded so rapidly under the direction of Mr. Ayers, and is now so far advanced that no delay from this cause is to be expected in the complete erection of the instrument. The shop work has included the right-ascension and declination slow and fast motions, the coude mechanism, portions of the insulating cover above the mirror cell, the declination counterweight system, and many other auxiliary attachments."
— *George Ellery Hale, 1916*







A massive iron "yoke" supports the 100-inch telescope. A special lift chair for observers using the Cassegrain focus rises on the northern pier and a platform to carry observers to the Newtonian focus hangs from the dome.



S. Adams, the men went into the silent dome. Ritchey, though present at the Mount Wilson complex, declined an invitation, saying that he did not wish to be present when the long endeavor was at last proved a failure.

As darkness fell, the astronomers trained the gigantic telescope toward Jupiter, and one by one they looked, then fell silent. It was just as Ritchey had predicted: the image of the planet was a distorted blob.

Hale would not admit defeat. He suggested that the distortion was due to the heat of the Sun, because the shutter of the dome had remained open while final adjustments were made on the instrument, and the giant mirror had absorbed the day's warmth. Later that night, he said, the mirror would be cool. The small group returned to Hale's residence at the site to wait, and perhaps fitfully sleep.

A few hours before sunrise they returned to the dome. Jupiter had set by then, so they aimed the big reflector at the star Vega. As each in turn looked through the eyepiece at the dazzling image of the star, they were relieved. The star appeared as a sharp and clean-cut point of light. Their hard work had paid off and Ritchey, though a defeatist, had by his genius and perseverance produced the largest and finest telescope ever built by man.

One of the first astronomers to use the new telescope was Edwin Hubble, who arrived at Mount Wilson in 1919. His chief task was investigating the distances of spiral nebulae that were then thought to lie within our own galaxy. By measuring the brightness of variable stars and using their pulsations as a measure of the star's intrinsic brightness, he found that the spiral nebulae were, in fact, galaxies, and that they lay at distances greater than anyone had previously imagined.

By studying the spectra of these galaxies and measuring the positions of their spectral lines, Hubble and his assistant, Milton Humason, confirmed and greatly extended an astonishing discovery made a few years earlier: the greater the distance of the galaxy, the faster it appears to be receding from us. These great investigations, pioneered at Mount Wilson in the 1920s, continue today under the direction of Allan Sandage, one of Hubble's pupils.

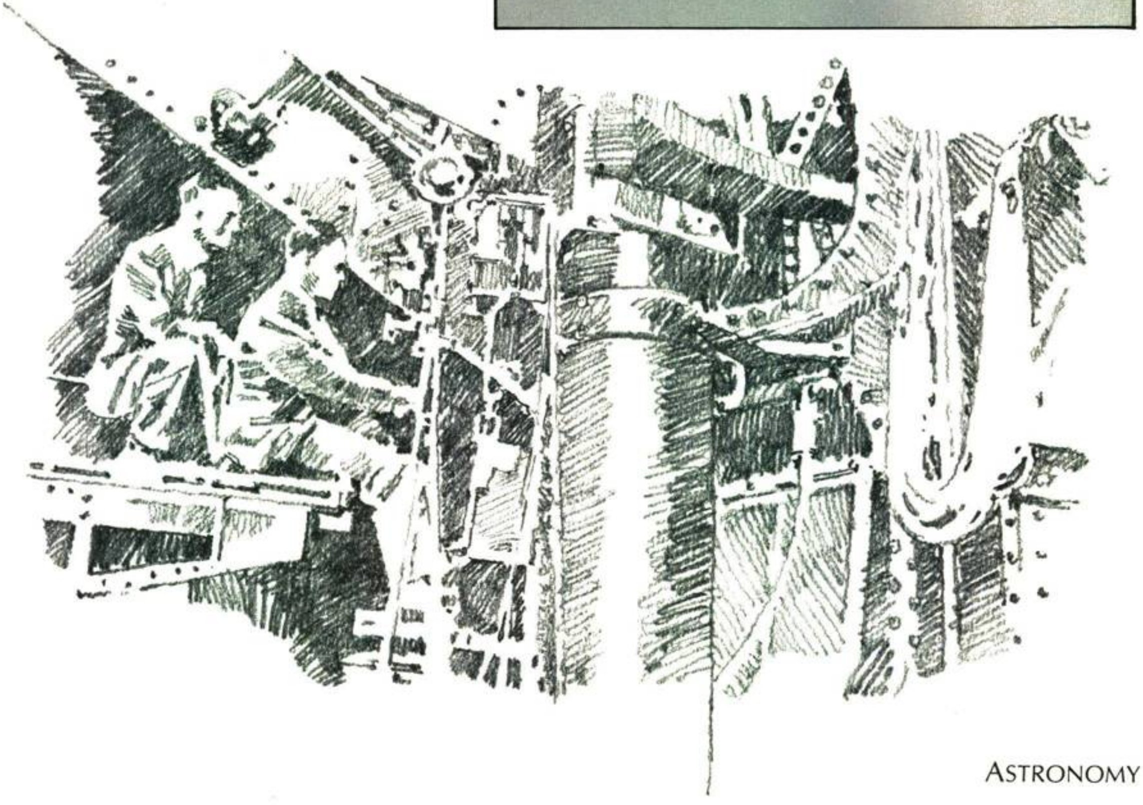
Many of the great discoveries made in astronomy during the period from World War I until about 1950, when the 200-inch telescope on Palomar Mountain went into operation, were made at Mount Wilson. A great deal of astronomical work, including the accumulation of an enormous collection of spectra from stars and distant galaxies, was performed there. For nearly thirty years Mount Wilson held the title of the largest telescope in the world. Even after the inauguration of its sister at Mount Palomar, the 100-inch was used to pioneer techniques like infrared photometry.

The work on the mountain, however, could not halt the expansion of the city that lay below the summit. The city of Los Angeles has grown nearly tenfold since 1917. During that expansion the city installed countless brilliant lights. Furthermore, automobile exhaust has filled the valley and contributes to that city's infamous brown photochemical smog.

In a decision taken in June 1984, the Carnegie

At the Nasmyth Focus

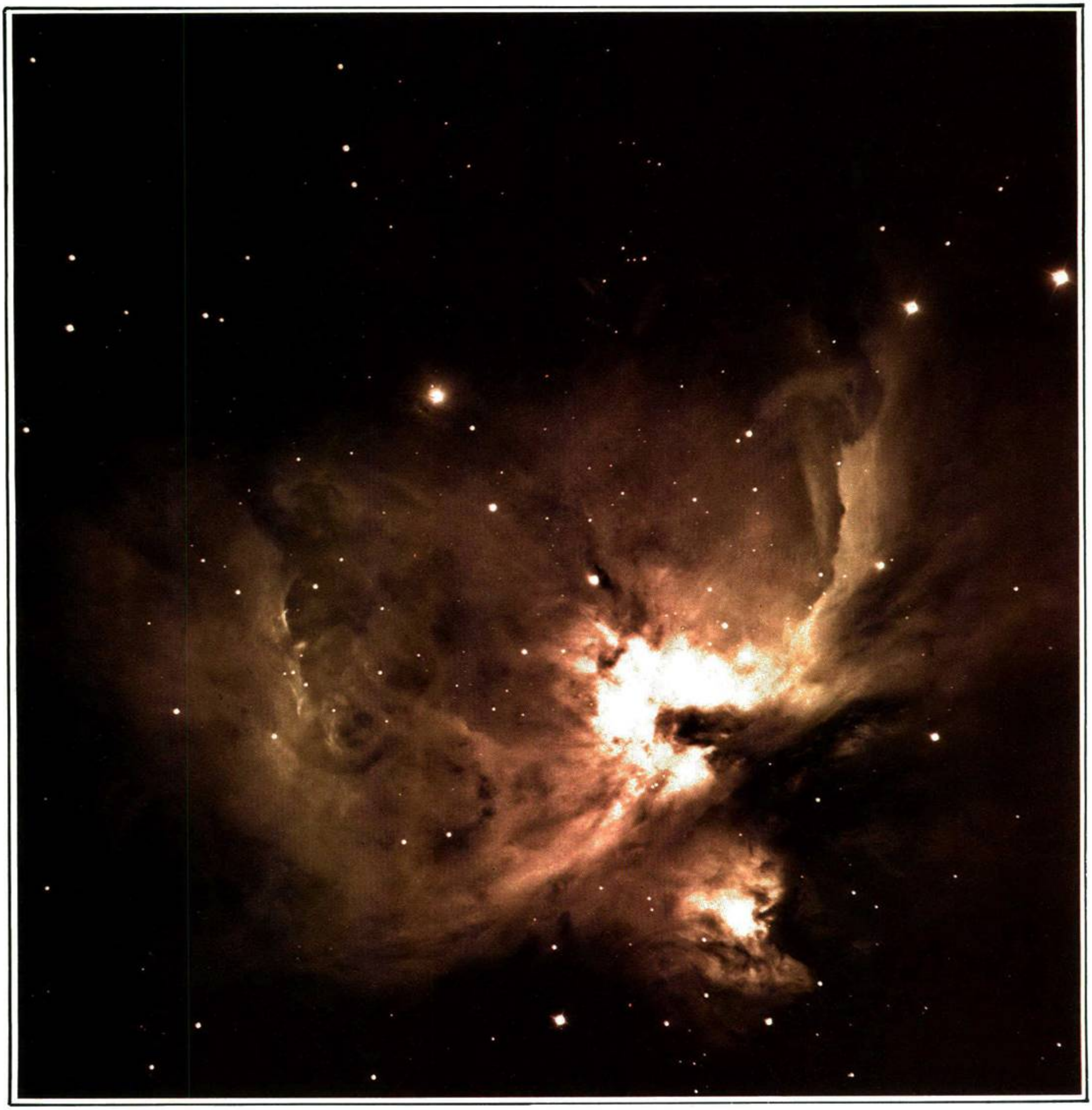
"The 100-inch Hooker telescope, though greatly delayed by the war, is now in regular use. It will therefore be of interest to give some details of the tests already applied, which leave no doubt that this powerful addition to the equipment of the Observatory will permit our observational program to be greatly extended." *— George Ellery Hale, 1919*

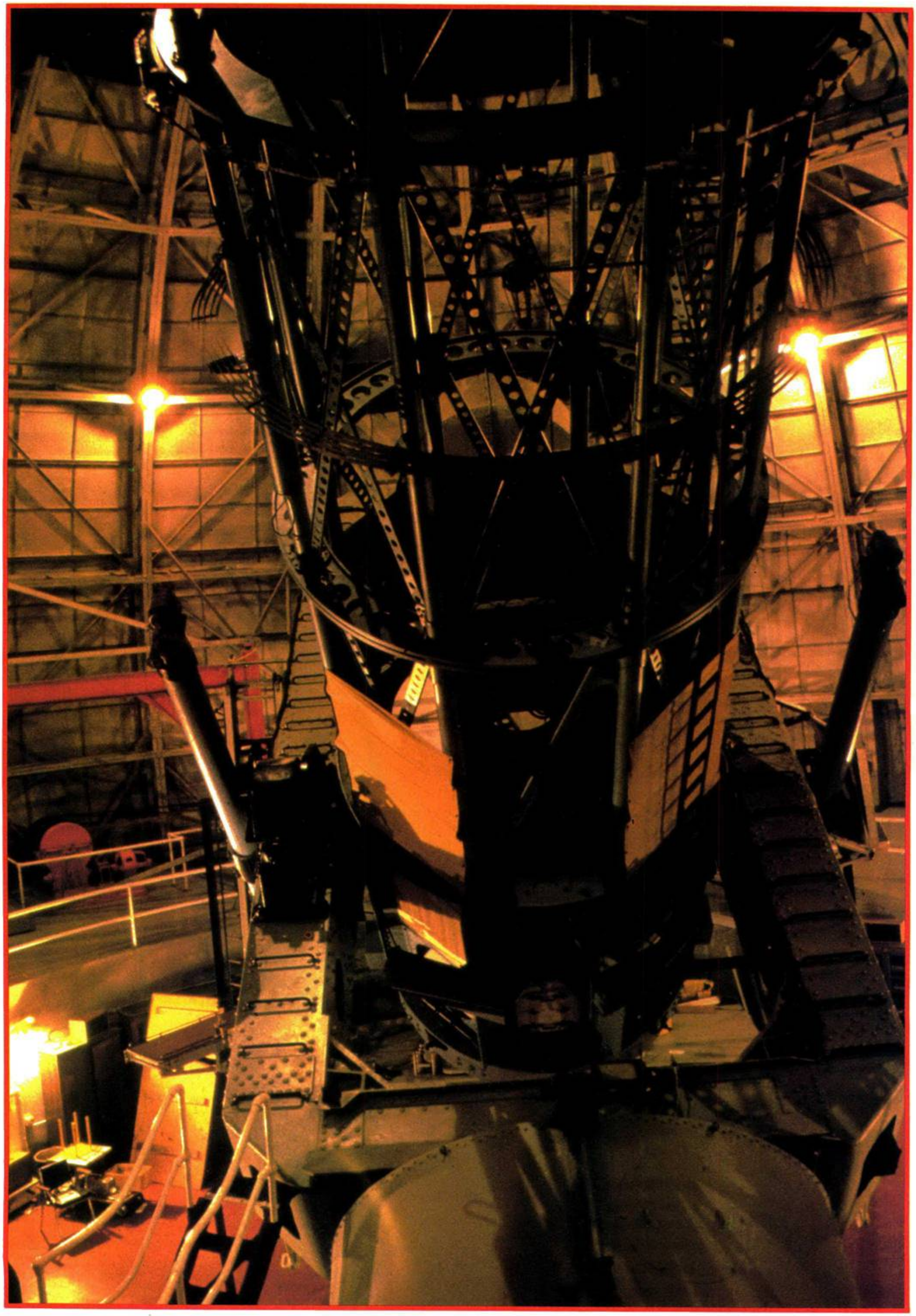


Institution decided to redirect its resources toward Mount Wilson's sister observatory in Las Campanas, where four telescopes of various sizes are already in operation, and an 8-meter telescope is planned. Funding for the Mount Wilson site was cut effective July 1, 1985, and the 100-inch telescope "moth-balled," meaning that although it is not in use, it is maintained so that it can be restored to operation if a suitably

Credits: M-31, pages 4-5 and 8; the telescope, 16-17; and M-42 on page 19 are courtesy of Hale Observatories and the Mount Wilson and Las Campanas Observatories. Quotes attributed to Hale on pages 9, 11, 13, 14, 16, 18, and 22 from the *Carnegie Institution of Washington Year Book* for the appropriate year; quote by Walter Adams from *Publications of the Astronomical Society of the Pacific,* vol. 59, p. 304, October 1947. Historical photographs on pages 4, 10-11, 12-13, and 14-15 are courtesy of the New York Public Library. Artwork on page 22 is by Victor Costanzo; the cover, pages 6-7, and sketches throughout are by Bruce Bond.

Unraveling the story of the birth, life, and decline of stars was one of the prime accomplishments of the Hooker telescope. The Orion Nebula, M-42, is a place where new stars are forming even now. This photograph was taken with the Hooker telescope.





Hooker Telescope Revolutionized Astronomy

From 1919 until it was moth-balled in 1985, the 100-inch telescope of the Mount Wilson Observatory never ceased making contributions to the science of astronomy. Its most dramatic discoveries came early.

The 100-inch telescope on Mount Wilson was responsible for the first really detailed photographs of "spiral nebulae." And the 100-inch revealed lots of them. According to an early estimate by Hale, the Hooker telescope could photograph at least 2 million "external galaxies," as they were then known.

Not only did photographs show structure, but they also showed fainter stars than anyone had ever seen before. Edwin P. Hubble's detection of the first Cepheid variable star in the Andromeda Galaxy in 1923 ended all argument over the nature of the spirals. "In the hands of Hubble," Hale was later to write, the 100-inch "has proved that they are in fact remote stellar systems, similar in structure to the Galaxy, of which our Solar System is an infinitesimal part."

But the most astonishing discoveries were yet to come. Hubble and Milton Humason, a mule driver and observatory janitor who proved in time to be a skilled observer, found that most galaxies were moving at high speeds away from Earth. The discovery of the expanding universe, which led directly to the Big Bang theory of its origin, is probably the most fundamental discovery of twentieth-century astronomy.

Stellar astronomy was another of Mount Wilson's strengths. Spectra of the white dwarf companion of Sirius confirmed Sir Arthur Eddington's prediction that old stars would collapse when they exhausted their nuclear fuel. The extremely high density of white dwarf material ('a steamshovel couldn't lift a teaspoonful of it!') was the darling of popular science writers of the 1920s and 1930s. At the opposite end of the scale, the Hooker telescope also helped unravel the mysteries of the stars we now call red giants, again, by means of a detailed study of their spectra.

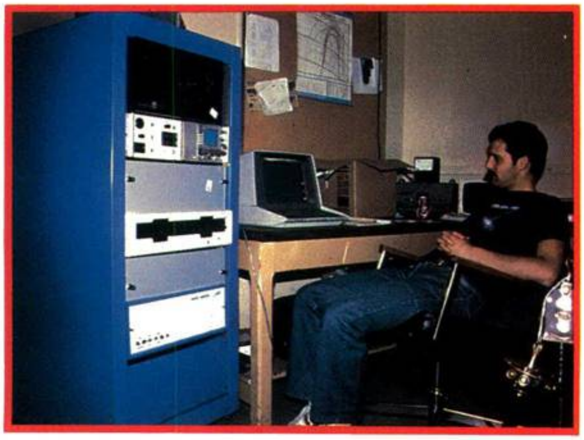
By 1930, when it was abundantly evident that the 100-inch telescope had opened the universe many millionfold, Hale said of the future, "Most interesting of all will be the interpretation of the apparent outward flight of the spirals, which seem to be receding from us at almost incredible velocities, increasing with their distance." But he stated that the observatory's long-term goal was "determining with certainty the successive stages in the development and motions of the spiral nebulae, a phase of evolution vastly transcending that involved in the birth, life, and decline of a particular star."

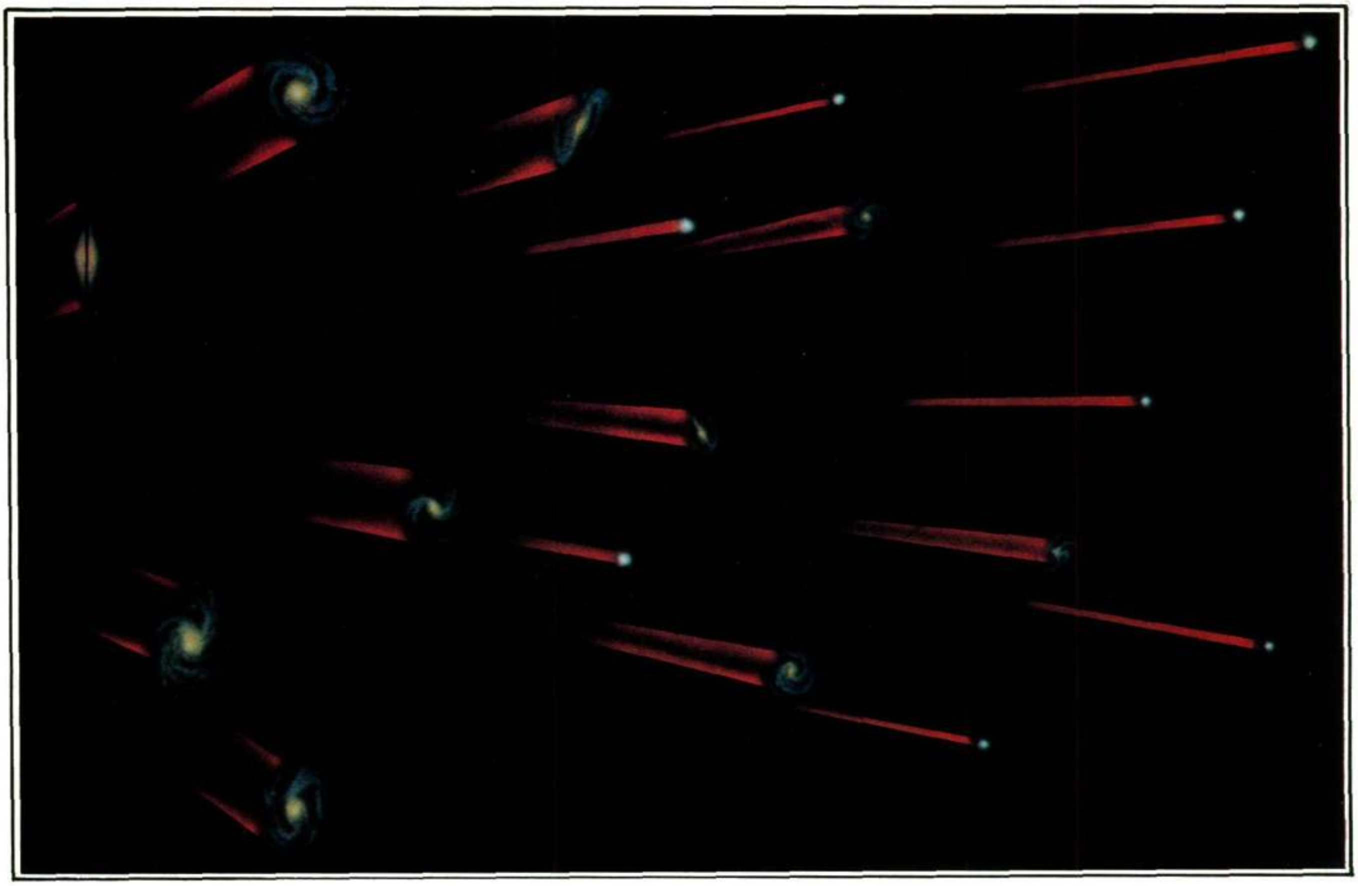
Even during the dark days of World War II, when most astronomers were doing research for the War Department, the Hooker telescope was not idle. Walter Baade, a naturalized German who was not permitted to do defense-related work, used the 100-inch telescope to photograph the barely-detectable variables in the Andromeda Galaxy night after night. Because Los Angeles was under blackout in fear of Japanese air raids, the skies over Mount Wilson were free of light pollution that even then hampered the big telescope's effectiveness, and Baade obtained the best measurements of their distance to date.

Soon after the 200-inch Hale telescope on Palomar Mountain became active in 1949, its powers eclipsed those of the 100-inch. In 1952, based on plates taken using the giant atop Palomar Mountain, Baade announced that his measurements with the Hooker telescope during the war (and all previous estimates) had been in error by 1.5 magnitudes, and that the Andromeda Galaxy and its companions lay twice as far away as had been thought previously.

As Los Angeles grew, light pollution increased. Gradually the 100-inch came to be less used for research on the cutting edge of cosmology, and more used for long-term programs that exploited its powerful coude spectrograph. Though less trendy than research on quasars and black holes, stellar astronomy is basic to astrophysics, and the 100-inch telescope was uniquely equipped for stellar spectroscopy. Until the day it was decommissioned, astronomers were using the Hooker telescope in a delicate spectroscopic search for "solar" activity cycles on nearby Sun-like stars. Its work is now ended.

Left: The 100-inch Hooker telescope as it appeared shortly before scientific work ceased in the summer of 1985.
Below: The observer's room of the 100-inch telescope. Post-doctoral fellow Geoff Marcy sits in front of support electronics for a photoelectric photometer. Photographs by Mark Coco.





Everywhere we look the galaxies are receding from us, and the farther they are, the faster they're moving. Using the 100-inch telescope, Hubble and Humason calibrated the redshift-distance relationship, which we now use as our fundamental cosmic yardstick.

funded scientific organization can be found to continue its operations.

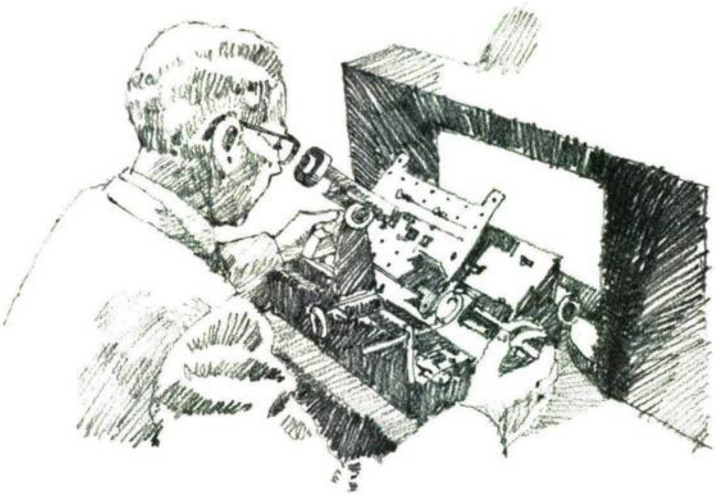
Astronomers from the University of California at Los Angeles and the University of Southern California, with separate funding, continue to use the solar telescopes at Mount Wilson. At night the glare of the city below seriously hampers the study of dim objects like distant galaxies. But city lights scarcely interfere with Mount Wilson's present specialty, high resolution stellar spectroscopy. The 60-inch telescope, with outside funding, continues to nightly probe the secrets of stars.

In the early 1900s the public imagination was captivated by the construction of larger and ever more powerful telescopes. People followed the progress of George Hale's dream with admiration and interest in the popular press. Today the world has changed. Whether we see the giant telescopes of the past as outdated museum pieces or as still-functional scientific instruments, few investments made have served mankind better as monuments to our ingenuity, determination, and desire to reach further and further into the universe.

Joseph M. Horodyski is a freelance writer specializing in science and history related articles.

At the Plate-Measuring Engine

"The 100-inch Hooker telescope, yielding results that are of service in all departments of the Observatory's work, has remained a center of interest throughout the year. In light-gathering power, in the photographic registration of minute details of structure, and in the separation and measurement, by Michelson's interference method, of double stars previously unresolved, this instrument has responded admirably to a wide variety of tests. Through its aid we have been enabled to carry our researches into new and profitable fields, thus considerably enlarging our research program. Before fixing the details of this program, it has seemed advisable to determine in what ways the capacity of the telescope could be most fully utilized, and for this reason much attention has been given to experiments with promising accessory apparatus and methods." — ***George Ellery Hale, 1920***



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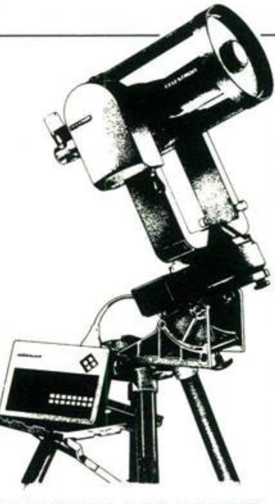
Ask about optional Declination and Focusing Motors!



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ASTRONOMY Forum

Memories of Sputnik

With today's cutbacks in NASA's operating budget, it is difficult to remember the time when the United States was feverishly reaching for space and cost was no object. But things were very different in the late 1950s. The successful launch of Sputnik in 1957 delivered a painful blow to America's pride and reputation as a world leader in technology. The jolt hurled the country into a space race that enjoyed the support of nearly every citizen.

The satellite programs of both the U.S. and the U.S.S.R. were coordinated with the International Geophysical Year, an eighteen-month period from July 1957 to December 1958 that was established to coordinate the study of Earth, its crust, and the space surrounding it.

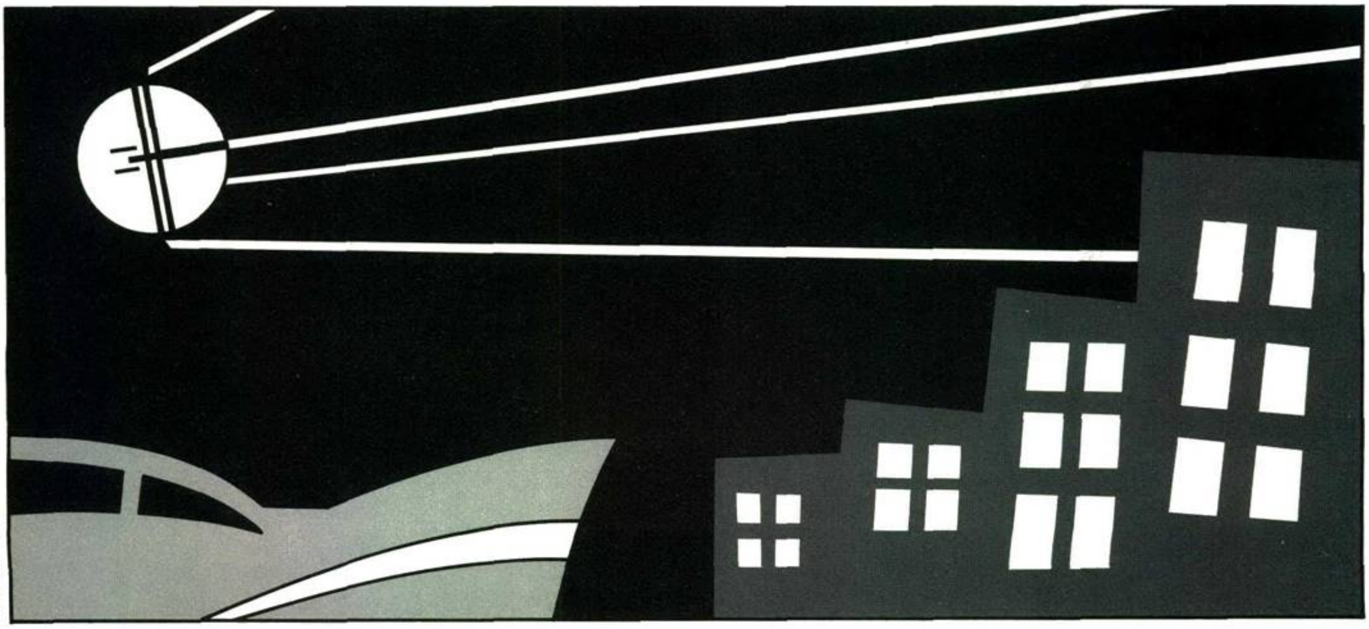
Although the Americans knew that the Soviets were planning to launch a satellite, they didn't know when. The U.S. had announced plans to launch a satellite sometime in 1958, and the Soviets had made announcements concerning successful rocket tests. However, Americans regarded the announcements as unsubstantiated Soviet boasts. Although the U.S. had not yet perfected its own rockets, it felt secure that it was ahead of the Soviet Union.

Lulled into complacency by its victory in World War II and its successful experiments with atomic energy, Americans — and the rest of the Western world — assumed that they would reach space first. The rocket that was to propel the first satellite into space would lift from a launch pad at Cape Canaveral.

Then, on October 4, 1957, the Soviets announced to the world that they had successfully launched the first artificial satellite, Sputnik. If Americans did not admit to a space race, the Soviets most certainly did, proclaiming themselves the winners and Americans the losers. Soviet astronautics expert Ari Sternfeld stated, "The launching of the Earth's first artificial satellite is a great victory for Soviet science and technology in the peaceful competition between the two systems of capitalism and socialism."

The Soviets were also quick to use the startling event for political influence. The official news release from the Soviet news agency read, "It seems that the present generation will witness how the freed and conscious labor of the people of the new socialist society turns even the most daring of man's dreams into a reality."

The news shocked and frightened Americans. President Dwight D. Eisenhower immediately conveyed his congratulations to the Soviets for their remarkable feat and then went about trying to calm the fears of the Ameri-



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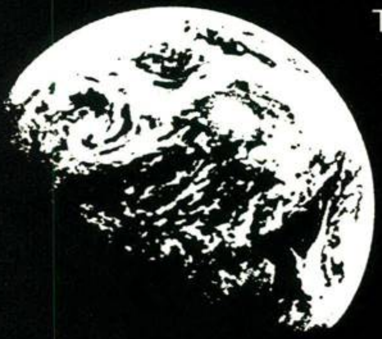

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can public. He insisted that America's own satellite program had never been conducted as a race. He told the people not to be frightened and that the Soviet feat was political, not military. Eisenhower said he was not concerned, "not one iota."

But the pain from a sorely bruised ego was not to be wiped away so easily. Americans were suffering from a severe case of humiliation. British journalist Patrick O'Donovan, commenting on the shock that was sweeping the nation, said, "Nor have the promises that Americans, too, will have their satellite, guilded for good measure and spinning for democracy round the Earth by the end of the year, made much difference. The central, inescapable pain remains and grows. And as strongly as any electorate can feel something that does not directly affect them, the Americans now feel and resent what they sense is a diminution in their status. The idea that a totalitarian state, bending its total efforts to a major research project, could outstrip the efforts of a rich democracy seemed in the end impossible to entertain."

With few exceptions, the first statements made by prominent figures after the launch were loaded with contempt for the Soviets and for American inaction, fear of the unknown, and panic-driven irrationality. On the day that the Soviet success became known, Rear Admiral Rawson Bennett, Chief of Naval Operations, belittled the feat, calling the satellite "a hunk of iron almost anybody could launch." The following day, Israel M. Levitt, director of Fels Planetarium at the Franklin Institute in Philadelphia, said it was "incredible stupidity" that kept the U.S. from winning the race.

Some congressmen, particularly Democrats, pointed fingers at the Republican administration, charging that Eisenhower's miserliness was the root of the problem. One congressman demanded an investigation by the Armed Services Committee. *Business Week* expressed the nation's fears by exclaiming, "Sputnik and its propulsion system, taken together, constitute a first-class intercontinental missile — plus trimmings."

The scientific community didn't seem surprised but did seem just as wounded. One scientist, who was attending a reception at a Soviet embassy, said he was "disappointed but relieved that the pressure is off. Now the job can be done correctly." Another scientist said, "Maybe the Russian-American competition hasn't been so bad if it encourages us into beating them to the Moon."

On the international front, America's reputation was quickly falling to second rate. The British press admitted that the Soviets were ahead of the West in some areas of science, reporting that many Englishmen were astonished that the U.S. wasn't the first into space. The French press also expressed surprise but went on to criticize the U.S. for its complacent attitude and for keeping secrets about nuclear energy from its allies. In Rome, newspaper editors saw Sputnik as a warning to the West to increase rocketry efforts.

A French columnist for the *New Yorker* reported that "in a jocular editorial, the liberal *Combat* said, 'Whatever one thinks about the Russians . . . one can't help saying that proud Uncle Sam has taken an awful beating, that his rockets are all wet.' " He reported that the French were analyzing Sputnik in four ways: "its almost majestic dominance as the No. 1 dramatic attraction of human interest around the entire world which automatically makes Russia the cynosure of universal attention; its power as a magnetic political instrument; its meaning as a potential military aid; . . . and, finally its mere entity as something not made in the U.S.A."

Americans demanded action. Some called for the government to get its own rockets off the ground regardless of the number of budget ceilings that had to be broken. Vice President Richard Nixon said that the U.S. must think of military strength as a matter vastly more important than cuts in taxes. Editorials around the country backed him solidly.

Meanwhile, Eisenhower tried to assess the potential ramifications from Sputnik and to recapture the trust of the American public. He maintained that the U.S. was not behind in the race with the Soviets at all, either militarily or scientifically, but he ordered the missile program sped up dramatically, nonetheless. In attempting to re-establish American prestige, his office issued a checklist of scientific achievements that included anti-submarine planes fitted with perfected depth charges, missiles so accurate they could shoot a flare-pot off the wing of a target plane, the accelerated development of the Polaris 15,000-mile missile, and a successful test from the satellite program.

On November 3, 1957, the Soviet Union delivered a second blow. It successfully launched Sputnik II, and this time a dog was aboard. This second launch was possibly more traumatic to Americans than the first. The shock of the initial launch was missing, but it added insult to a critically injured pride. America was still on the ground and there was little hope that there would be a space shot in the near future because of mechanical problems.

Furthermore, Sputnik II was nearly fifty times as heavy as any satellite America proposed to launch, fueling the controversy about inferior U.S. rockets that were unable to compete. Moreover, the fact that the second launch followed the first by just twenty-nine days led frightened Americans to speculate that the Soviets had a stockpile of missiles.

The President, at last, admitted that "it is entirely possible that in years ahead we could fall behind . . . unless we now face up to certain pressing requirements and set out to meet them at once." In the same speech, he announced the creation of the position of Special Assistant to the President for Science and Technology. The move was made to achieve greater concentration of efforts and facilitate the transfer of information within the government in the area of technology and missiles.

Yet fate seemed set against the Americans. The rocket that was supposed to propel a 3.2-pound test satellite into orbit exploded on the launch pad. America was again a failure. It was not until January 31, 1958, that America joined the space race with the successful launch of Explorer I. The event was somewhat anticlimactic. When physicist Edward Teller was asked what he expected to find on the Moon when and if the Americans ever reached it, he replied, "Russians."

In May, the Soviets launched the third Sputnik. This one weighed more that a ton, a feat no one else could match.

Journalist William Shelton, a specialist in U.S. and Soviet space programs, said that the Soviet feats "immediately precipitated in the United States one of the most intensive soul-searching and re-evaluations we have ever undergone. We pondered our assets and took stock of our real or suspected deficiencies."

America did take stock and threw itself into a frenzied race to the Moon. It was twelve years before Neil Armstrong stepped on the Moon, and Americans claimed that victory. The nation was giddy with joy as the world watched the American flag being stuck into the lunar soil on live television.

An editorial in *The Nation* reflected the mood of exuberant Americans: "Over the past twelve years, we have successively been challenged, enraged, and spurred into action — and have demonstrated to all our courage, strength, speed, ingenuity, and technical skills."

The shadows of Sputnik had faded, and Americans realized that they were indeed a dominant force in space.

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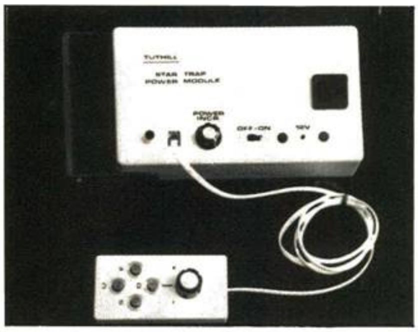

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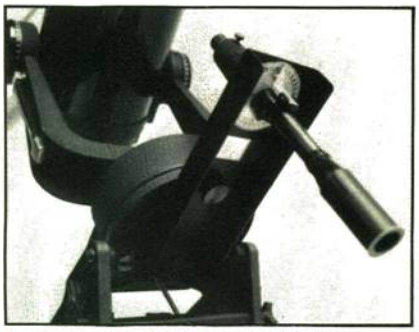

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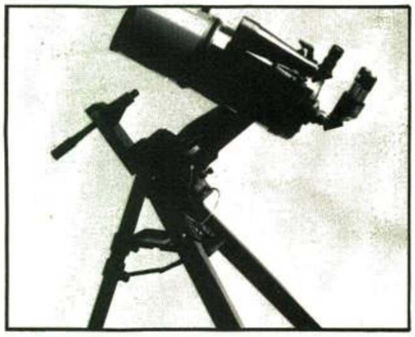

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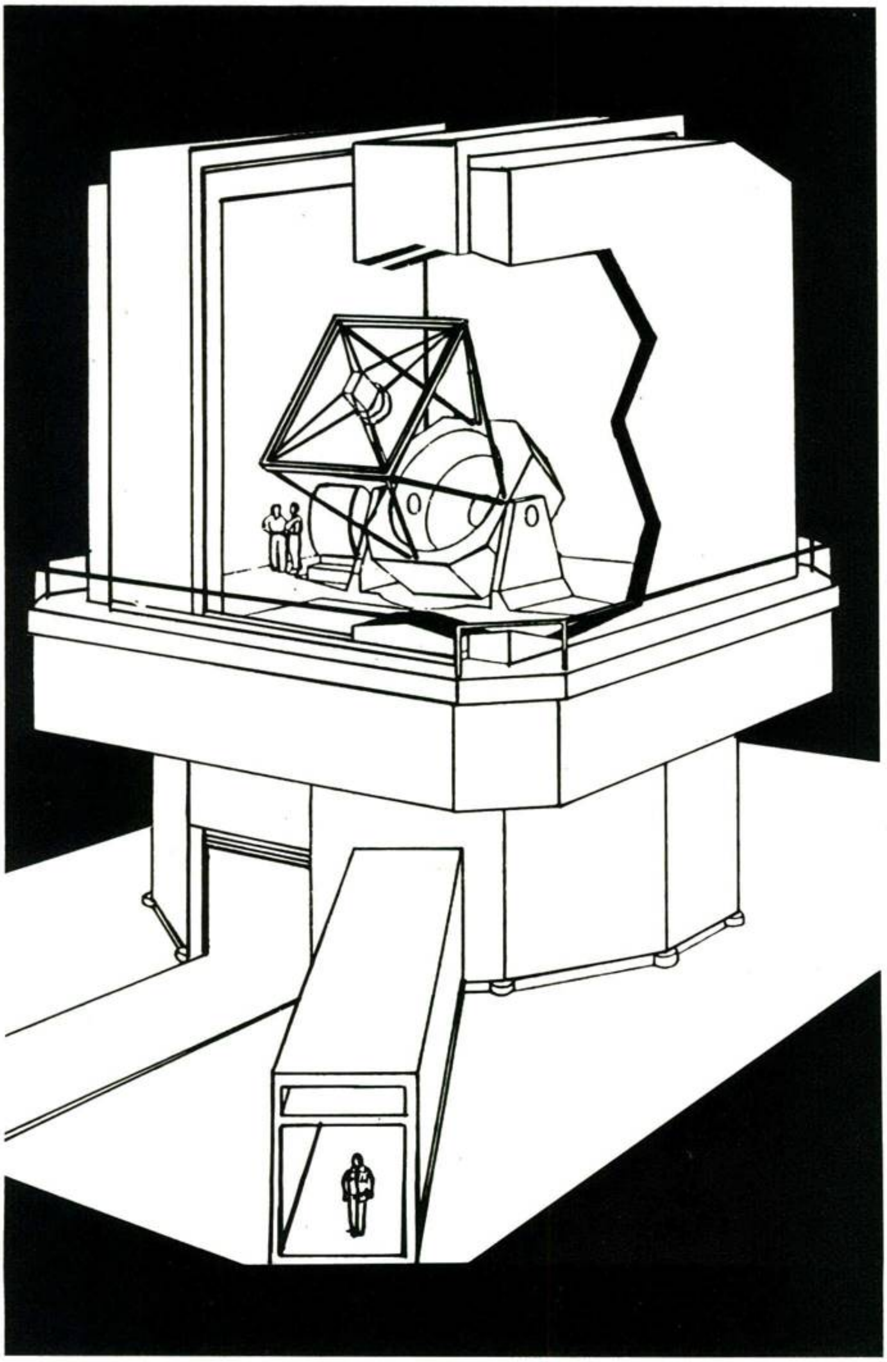
The Clyde Tombaugh Visiting Scholars Program

In 1930 a young farm-boy astronomer named Clyde W. Tombaugh discovered the planet Pluto. Hired as a research assistant at Lowell Observatory to carry out a photographic search for Percival Lowell's "Planet X," the young man soon realized that the observing program he had inherited was poorly planned and stood little chance of success. After reorganizing the schedule for exposing the search plates, the young astronomer determinedly kept at the rigorous task of blinking them in search of the tiny speck that would herald the new planet. Within the year he had found it.

For the young astronomer the job was the ideal opportunity to get into professional astronomy. The young man brought fresh ideas, energy, and enthusiasm to the search for Planet X. To the world he and his employer contributed a new planet. And to an observatory that the independently wealthy Lowell had established for studying the Martian canals, he brought recognition and a legitimate claim to fame.

Now, fifty-six years after his discovery, Clyde Tombaugh is making another contribution to astronomy. He is giving his name to a fund-raising effort on behalf of New Mexico State University: the Clyde Tombaugh Visiting Scholars Program. His purpose is to help the astronomy department endow research positions for young astronomers and to help talented young people begin careers in astronomy.



It came as something of a surprise to me when, early last spring, Reta Beebe of New Mexico State University called to ask if I would be willing to participate in helping the university officials raise funds for the Tombaugh Scholars. Would I be willing to fly out to New Mexico and spend a day discussing the program with university officials? Even though I said, "I don't know from Adam about fund raising," I got snagged somewhere along the way because the whole concept sounded intriguing, and it's the kind of research opportunity that ought to exist somewhere on this planet.

New Mexico State University has a very small but very serious astronomy department, a department which Clyde helped establish in 1955. Soon these astronomers will have access to a 3.5-meter telescope — the Apache Point telescope — roughly fifty nights a year. It's a tremendous opportunity for every person in the department, but a big responsibility. What is the best way to use such a wealth of observing time on a major instrument? Who can do that much observing and still teach the next day? In short, how can a small astronomy department conduct world-class astronomy in a field dominated by big, well-endowed universities?

It sounded like an interesting problem. So I flew to El Paso last August 18 and was met at the gate by Bernie McNamara of the NMSU Department of Astronomy. Bernie has been involved in the Tombaugh Visiting Scholars Program from the very start. As we drove toward Las Cruces, he explained that NMSU wanted to try something different — to raise significant funds for the Tombaugh Scholars from amateur astronomers and amateur astronomy groups. "Clyde started out as an amateur astronomer," he told me earnestly, "and this program will be in his honor." He talked about how the program would provide a young astronomer with extraordinary opportunities for research. "It's a better position than any of the faculty has," he noted.

Tombaugh scholars will be chosen on a nationwide competitive basis, and most of them will be postdoctoral fellows, that is, young astronomers who have just finished a doctoral dissertation and are deeply involved in astronomical research. "With employment like it is nowadays," said Bernie, "there aren't many postdocs. People

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have to take the first job they can get, and that usually means there's no time left for postdoctoral research."

While the bulk of the $1 million endowment will be raised from foundations and matching grants from the State of New Mexico, the New Mexico astronomers hope to raise at least $50,000 from the amateur community. By raising funds for an endowment, instead of spending funds directly, the program is guaranteed a long life. All donations will be held in a trust fund, and the income from the fund will be used to run the program. That means that a $100 donation will provide something on the order of $6 to $8 every year thereafter.

In the evening I had dinner with Reta and Herb Beebe from the Department of Astronomy; Jim Halligan, the president of NMSU; the officials from the university's Office of Development; and, of course, Clyde Tombaugh and his wife Patsy.

I had met Clyde before but had never had the chance to talk with him for any length of time. Of course I had read his book, *Out of Darkness: the Planet Pluto,* coauthored with Patrick Moore, on the discovery of Pluto. But that night Clyde was full of stories of the White Sands Missile Range where he spent ten years after World War II as the head of photographic missile tracking. His films provided vital flight data on the performance of captured German V2 rockets and the early American rockets designed by the German missile teams, especially when they malfunctioned. Clyde recalled, with a shudder, the time one rocket crashed a hundred yards from one of the tracking camera stations. "I saw the camera station disappear in a big cloud of dust, and I was sure that I'd lost a camera crew," he said, but the men "hit the deck" and were not injured.

When he left White Sands, Clyde came to New Mexico State University and, after a short period of time, helped establish the Department of Astronomy there. He served in the department for eighteen years, and though he retired some years ago, he is still professor emeritus and maintains an office in the department.

After sixty years in and around professional astronomy Clyde still has a lot of the amateur energy and enthusiasm left. He invited me to come out to his house at 1:30 a.m. to observe Jupiter. "It's really great this year," he said. "This is a perihelion opposition, and *Jupiter's equatorial* diameter is 48 seconds of arc." If I had had any way to get across town in the middle of the night, I would have taken him up on his offer. As it was, we agreed to meet the next day.

In the committee meeting the next day I was able to help the university fundraisers establish the size of the "total universe" of amateur astronomy, roughly 250,000 strong, and suggest a realistic percentage of response that a direct mail campaign might draw from a "list," such as a list of ASTRONOMY readers. (Don't be surprised if you receive a mailer from NMSU in the next six months asking for your contribution or see appeals for donations to the Tombaugh Visiting Scholars Program in various magazines and newsletters. That's what our meetings were about.)

In the afternoon, after a tour of the Department of Astronomy's building where I saw two of Reta Beebe's graduate students doing real-time image processing of Voyager pictures of Jupiter using a PC/AT-based image processing system, we drove over to Clyde Tombaugh's home. It is located, as the punster in Clyde most certainly appreciates, at the corner of "Western" and "Union."

The telescopes were readily visible in the backyard as he came out to greet us. Behind the clothesline was the 9-inch reflector that the young Tombaugh used in the summer of 1928 to make the drawings of Jupiter that ultimately netted him the job at Lowell Observatory. Behind the 9-inch was the 16-inch, a massive framework of angle iron that towered some 20 feet over our heads. The tube is an open framework large enough and long enough to accommodate both telescopes. A massive yoke mounting supported the tube. Clyde Tombaugh is proud of the instrument and has used it this summer to observe Mars and Saturn.

Virtually surrounding the telescope are the platform and stair that allow the observer to stand 16 feet or more above ground level to reach the eyepiece. Even hardy souls may quake at the thought of standing on a box balanced on planks across the rails of the main platform, but the octogenarian astronomer does it routinely for observations near the zenith.

The telescope's finder is the first American richest-field telescope — a 5-inch f/4 Newtonian. Albert Ingalls estimated, according to Clyde, that 60,000 people built telescopes in the 1930s, inspired, in part, by this little galvanized-iron telescope. The discovery of Pluto made Clyde a real folk-hero during the dark days of the depression. Astronomy in the shape of a home-built telescope served as a low-cost and satisfying pastime.

Besides keeping up observations of Mars and Jupiter, Clyde is still helping out fellow amateurs. He showed me — with pride — a portable 8-inch equatorial reflector he's helping a local amateur astronomer build. The freshly painted square plywood tube rested across sawhorses in the side yard. The entire telescope will be carried on an old power lawnmower chassis, as Clyde's own 10-inch f/5 Dobsonian telescope is.

I asked Clyde if he was truly one hundred percent behind the Tombaugh Visiting Scholars Program. He grinned. "Yes I am," he said, "and my family is, too. That is important, you know." We stood there in the yard, me and the man who found Pluto, photographed rockets, and built telescopes.

"I had to be sure," I said.

"I understand."

As Reta and Herb Beebe drove me back to the airport along the smaller roads that parallel the Rio Grande, past cotton and peppers and pecan trees, Herb mused about the role postdoctoral fellows play in astronomy departments. "They really contribute a lot of energy," observed Herb. "They have a couple of years to do what they want to do, without teaching responsibilities. And the grad students really learn from them."

I recalled my own years as a graduate student and the postdocs I encountered. The professors always seemed busy, burdened with a million responsibilities, authoritative, conservative, and stodgy. Postdocs, on the other hand, had zest. Their doctoral rite-of-passage completed, they now sought projects that interested them. One young British astronomer I knew, in the course of a year, modeled galactic collisions on a Hewlett Packard computer with only 4K of memory (a *mini*-computer in those days!), searched for the optical counterpart of Cygnus X-1, tried to detect the Crab pulsar at optical wavelengths, and "tried on" radio astronomy at the 150-foot dish at Algonquin Park in Ontario. He inspired me, and from him I learned more about what a thrill astronomy could be than I did from all the rest of the faculty combined.

Astronomy is changing these days in unpredictable ways. Federal support is no longer the only driving force. Advances in instrumentation — from the $10 million investment a 3.5-meter telescope represents to an image processing system that costs only $10,000 — offer opportunities for research in astronomy that nobody even dreamed of twenty years ago.

But the bottom line is still this: the future of astronomy depends on finding the right people and on giving those people the opportunity to do astronomy. That is why the Tombaugh Visiting Scholars Program, named in honor *of a young man who was put in* a position where he could excel, deserves our support.

— *Richard Berry*

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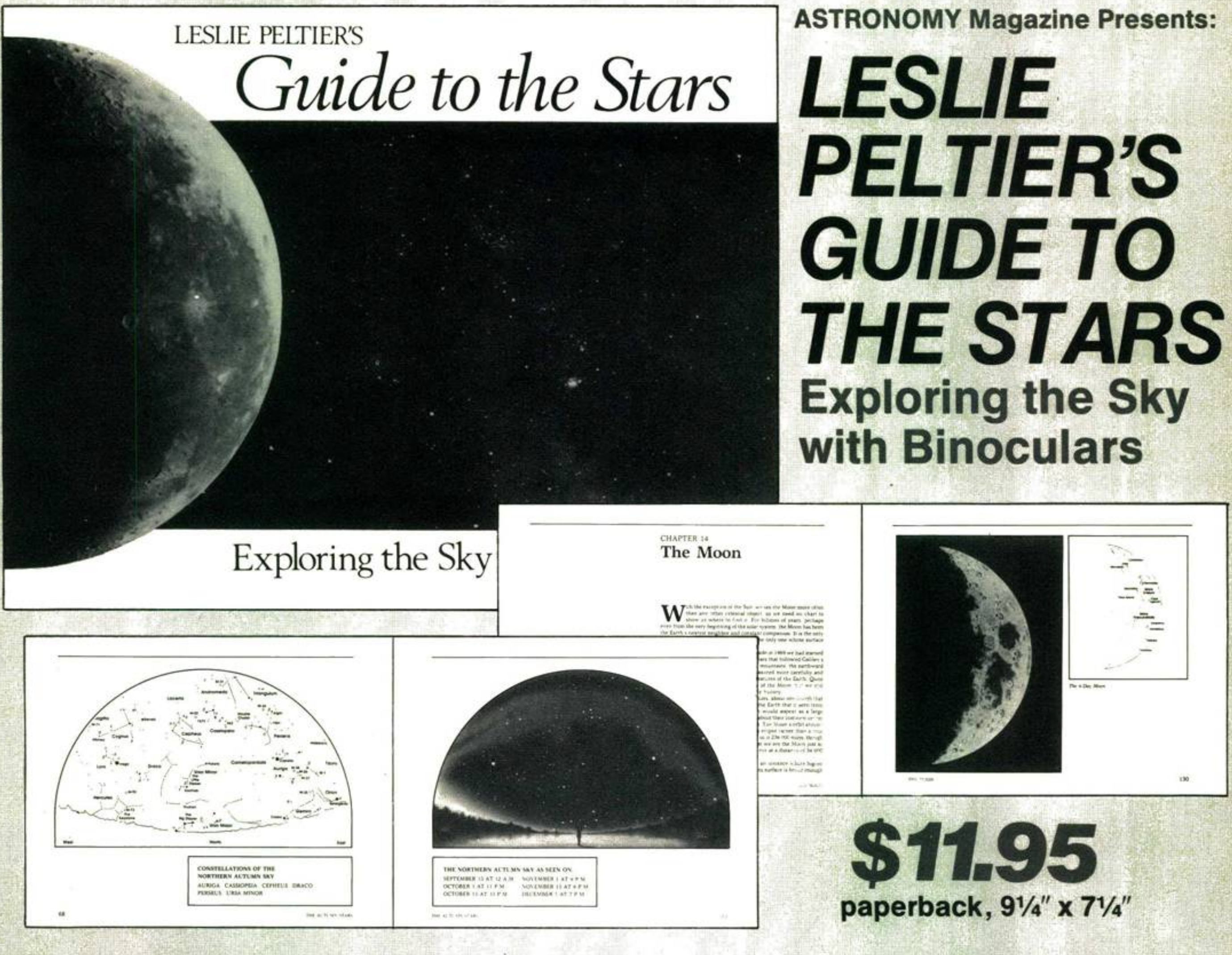
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The Spelling Lesson

The clock said two o'clock, and Mrs. Rosetta told her third grade pupils to get out their pencils and notebooks. It was time for their spelling lesson.

"Today we are going to learn words of science," she said. "Who can give me a definition of science?"

Several children shot up their hands. Mrs. Rosetta called on Jennifer.

"Science is finding out things about the world," said Jennifer.

"That's a pretty good definition of science," said Mrs. Rosetta. She wrote the word "science" on the blackboard and the children copied it down in their notebooks.

"Let's start with the word 'universe.' The universe is everything there is — space, stars, planets, your houses, and you, too." She wrote "universe" on the blackboard and said, "Repeat after me. U-N-I-V-E-R-S-E."

The children said in unison, "U-N-I-V-E-R-S-E," and copied it down.

"Another word for universe is 'cosmos,' " said Mrs. Rosetta, writing it on the blackboard. "Repeat after me. C-O-S-M-O-S."

"C-O-S-M-O-S."

"Scientists think the universe began very long ago," she said. "You remember we talked about this in science class. The universe began in a great explosion called the Big Bang."

She wrote "The Big Bang" on the blackboard and the children copied it, except for Jimmy Bates, who leaned toward Bobby Johnson and whispered, "Wanna see a big bang?" A pink bubble emerged from his mouth and quickly swelled — and popped.

Out of nothingness it emerged, a tiny bubble of space-time. It swelled with incredible speed, and the energy of its expansion was transformed into a deluge of radiation and quarks. For a millisecond the quarks swarmed through this radiation in total chaos, but this would be the one and only millisecond of total chaos in the history of the universe. At once the quarks bound themselves into pairs and triplets. Out of chaos, order began to emerge.

"Our next spelling word is 'quark.' Q-U-A-R-K."

The class repeated, "Q-U-A-R-K." Several of the children giggled.

"Quark is sort of a funny name, isn't it?" said Mrs. Rosetta. "But quarks are very important things. They are little bitty particles, so small you can't see them. But they make up everything in the world. Stars, trees, houses, snowflakes, even all of you."

Aa Bb Cc Dd Ee F
DOG
Multicellular
ORGANISMS
CAT
? ?? ?? ?

Todd Graveline

As the different types of quarks combined in different ways they created many kinds of particles, including neutrons and protons, which began combining into atomic nuclei. Much later these nuclei combined with electrons to form atoms. When stars formed, neutrons and protons combined in their interiors to form heavier nuclei, such as oxygen, calcium, and carbon.

"I'm sure you all know what a star is. Who knows how to spell 'star'?"

Several arms made of oxygen, calcium, and carbon shot into the air, fingers wiggling. Mrs. Rosetta called on Clare.

"Star is spelled S-T-A-R."

"That's right," said Mrs. Rosetta, writing it on the blackboard. "And a huge bunch of stars is called a galaxy." She wrote "galaxy" on the blackboard and said, "G-A-L-A-X-Y."

"G-A-L-A-X-Y."

"And what is it that moves around a star? Clare?"

"Planets."

"Right. Do you know how to spell 'planet'?"

Clare said slowly, "P-L-E-N . . . P-L-A-N-I-T."

"Almost. Does anyone else want to try?"

Frank Dobbs raised his hand. "P-L-A-N-E-T."

"Good, Frank." She wrote it on the blackboard. "Everybody. P-L-A-N-E-T."

"P-L-A-N-E-T," the children said and wrote it down.

"And what goes around a planet? A moon, of course. Can anyone spell 'moon' for us?"

Frank Dobbs tried, "M-O-N-E," and then Clare got it right, "M-O-O-N."

"Good, Clare. M-O-O-N."

The class repeated, "M-O-O-N."

As order emerged on the atomic scale, it also emerged on the cosmic scale. The chaotic matter flowing out of the Big Bang began dividing into billions of clumps. The clumps continued taking shape and became galaxies, each containing billions of stars. Around stars matter formed into a new kind of body. The conditions weren't always right, so often the effort failed, but here and there matter took the form of *planets*.

At first the only planets were made of hydrogen and helium gas. Yet as stars created heavier elements and spewed them through space, planets of solid matter formed. As the elements combined in different ways they formed planets of ice, rock, deserts, volcanoes, oceans, and every mixture

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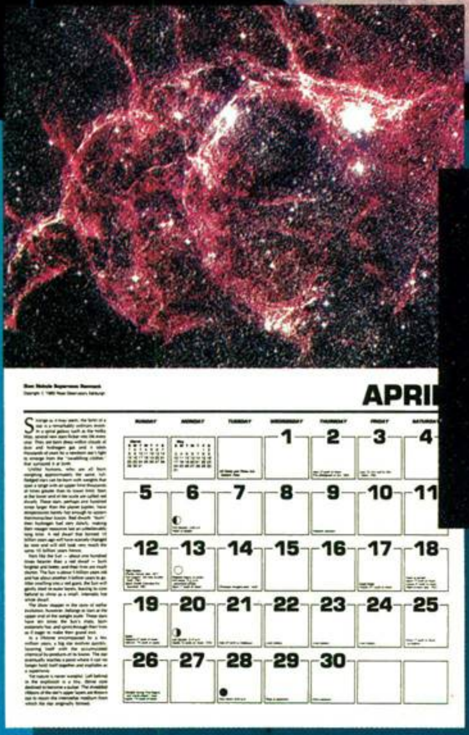

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thereof. They also formed many kinds of *moons*.

"We've spelled a lot of words from the science of astronomy," said Mrs. Rosetta. "Now let's try some words used in biology. Biology is the science that studies life." She wrote "life" on the board. "Let's spell 'life.' L-I-F-E."

And two dozen lives responded, "L-I-F-E."

On some planets a new kind of order emerged. Carbon atoms flowing through the oceans mixed together and, energized by wind and waves, lightning and sun, formed large molecules. The molecules became increasingly sophisticated, and as they combined in various ways they were able to do some sophisticated things. Some molecules could form spheres, some could imprint their form onto other molecules, some could hold an electrical charge. The molecules must have come together in countless billions of ways, then broken apart before they came together in the right order to form a working cell. The universe had learned something new: *life*.

"All living creatures are made of tiny units called cells," said Mrs. Rosetta. "Repeat after me. C-E-L-L."

"C-E-L-L," replied the little repositories of cells.

It had taken a long time for chaotic molecules to form the first cell, but then the creation of more cells was easy. The first cell was able to imprint its order onto the chaotic molecules around it. It said to them, "Repeat after me: C-E-L-L."

And the molecules said, "C-E-L-L. C-E-L-L. C-E-L-L. C-E-L-L. C-E-L-L. C-E-L-L. C-E-L-L. . . . " Before long a whole planet was covered with cells.

"Another important word in biology is evolution. Scientists think that life started out as something very small and simple a long time ago. They think life has slowly changed into more complex forms. Repeat after me, E-V-O-L-U-T-I-O-N."

"E-V-O-L-U-T-I-O-N." Several of the children mixed up the last letters.

The first cells were very simple, but as they reproduced, the sequence of their genes was occasionally altered and the cells ended up with new forms or abilities. If a new form or ability helped a creature survive, it was more likely to be transmitted to the next generation.

"That's E-V-O-L-U-T-I-O-N," said Mrs. Rosetta.

"E-V-O-L-U-T-I-O-N," said the children.

Through trial and error certain molecules came together in the right way to capture and utilize the energy of the sun — *photosynthesis*. Cells joined with other cells to form *multicellular organisms*. Such organisms adopted several ways of living, such as being *plants* or *animals*. Their bodies were shaped in various ways, enabling them to move about in the water, underground, on land, and in the air. They perceived what was going on around them through their senses, and to process that information they used a . . .

"B-R-A-I-N," said Mrs. Rosetta.

"B-R-A-I-N," said the children.

Creatures eventually utilized sounds and molecules in complex ways so they could share information with one another. At first such messages were simple and stereotyped, but as brains grew better at processing information, they could create and decode much richer messages. When humans evolved, communication became richer than ever. Humans not only developed a sophisticated spoken language, they invented something entirely new — written language. By various arrangements of the handful of symbols in an alphabet, humans were able to represent everything in the universe.

"Discover," said Mrs. Rosetta. "Discover means to learn things, to find out things. Scientists discover the secrets of the universe. Now repeat after me. D-I-S-C-O-V-E-R."

"D-I-S-C-O-V-E-R."

Yet the alphabet was not entirely a new invention. Humans had simply discovered a new application for an ancient principle that has been at work in the universe from the very beginning. This principle states that combining a handful of units in various ways produces a dazzling diversity of forms and powers. All of cosmic evolution has consisted of working out this principle on one level after another.

From quarks to protons and neutrons to atomic nuclei to atoms to stars, from planets to organic molecules to genes to life to brains, matter found novel expressions in these different organizations. The nature of matter made possible a vast hierarchy of order. If the nature of matter had been different, leading to too little or too much order, the universe might have gotten stuck in chaos or rigidity at any step of the way. The universe might consist of nothing but quarks unable to combine, or quarks cemented into one giant block. Yet the nature of matter made possible just the right order and flexibility for quarks to build all the way to life. Sometimes the order of one level not only made possible but actually forced the emergence of the next level of order. More often a great deal of time and energy went into building the next layer of order. The blackboard of space slowly filled with objects. And then the universe learned how to spell . . .

"H-U-M-A-N. That's us," said Mrs. Rosetta, "that's the name of our species. Repeat after me. H-U-M-A-N."

As the children spelled the word, activity swarmed through the intricate system inside their heads. Electrical impulses raced down billions of neurons, fizzling out on some pathways and on others adding up like the water in tributaries flowing into a river. Messenger chemicals rushed back and forth between neurons. Inside the neurons molecules swarmed about, energy flowed, the genes spewed out instructions, and molecules broke apart and reformed with new meanings. Different sectors of the brain volleyed information back and forth.

The children spell "human" with only five letters, but the universe spells human with an unimaginable number of letters arranged in the intricate order that is the human brain. This order incorporates other levels of order that have previously emerged in cosmic evolution. The quarks that bound themselves together in the first millisecond of the Big Bang are in there. So are atomic nuclei, atoms, the complex molecules produced in 4 billion years of evolution, and cells of many forms and functions. Out of these simpler layers of order has arisen a higher order, a brain that can discern all the layers of order in the universe and glimpse the 15-billion-year process through which they all arose.

Atop that 15 billion years of order, the human brain began generating a strange new layer of order. Humans studied the universe and slowly translated its order, its language, into human language. In the human brain the entire universe was constructed anew, but with something added.

In the human brain the universe finally learned how to spell "I am." The universe learned how to spell "The universe is amazing."

"That's it," said Mrs. Rosetta. Speaking these words continued the ordering process that began 15 billion years before. In the head of each child, the magic loom swept back and forth, weaving her sound waves into meaning.

"That's our spelling lesson for today."

Don Lago
Columbia, MO

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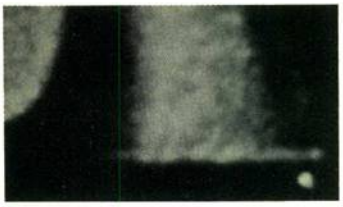

From photographs taken during NASA Voyager 1 flight to Saturn, the author shows how Saturn's rings are made. The ring gaps also fit into the explanation; and many questions asked since Galileo are answered. A correlation is also shown between a Ringmaker and the crater, Mare Orientale, on Earth's moon. Ringmakers constitute a compelling reason for implementing the U.S. Civilian Space Program.

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In Focus

Planetary Nebula Not So Faint

Sir / August's Backyard Astronomer said that the planetary nebula IC 1295 in Scutum "glows dimly at 15th magnitude." Although such depressingly faint photographic magnitudes are often quoted for planetaries, their visual magnitudes are often up to two magnitudes brighter.

This discrepancy occurs because photographic emulsions are relatively insensitive to the oxygen III spectral lines at 496 and 501 nanometers, where most planetaries have their peak emission. Fortunately, this wavelength corresponds to the human eye's peak sensitivity.

I recently glimpsed IC 1295 with a 5-inch reflector at 62x and can happily report it is no fainter visually than 13th magnitude.

Steve Gottlieb
El Cerrito, CA

Viewing Venus by Day

Sir / In the August 1986 "In Focus," Peter Wilson shared a way to find and observe Venus by day. On July 9, while I was showing my kids some sunspots using a solar projection screen, I remembered Mr. Wilson's letter and tried unsuccessfully to find Venus. The Moon was not "findable" either, as it was only a very slight crescent the night before.

However, we tried again in the early afternoon of July 11 and easily found the crescent Moon despite the occasional intrusion of fluffy clouds. Then we began scanning the general area between the Sun and Moon with 10x50 *binoculars*. Finally we found Venus!

The trick was to find Venus in the binoculars and then zero in with the telescope. The glare-free "half-moon" phase was indeed the best we've ever seen of Venus.

It was especially exciting to find the planet in broad daylight only six months after getting interested in astronomy. It's very helpful to read "tips" in your magazine that are useful even to the inexperienced.

Howard Maxson
Hammond, NY

Small-Telescope Club

Sir / I am inviting all small-telescope users to join the Small Scope Observers Association (SSOA). This is an international organization of small-telescope users who have united in the spirit of friendship and research. We feel that the capabilities of small telescopes have long been overlooked.

We already have several members studying the planets, Moon, and Sun, and we hope to soon have a variable star and meteor watch section as well. There is also a group newsletter that any member may contribute to.

But you don't have to do research or writing if you want to join the SSOA. The organization is open to everyone regardless of equipment or experience, and membership is free.

For more information on the SSOA, please write to me.

Robert Browning
4 Kingfisher Pl.
Audubon Park, NJ 08106

Unusual Observing Experiences

Sir / British telescope maker James Nasmyth's favorite observing site was near a river that flowed through his property. Often, he would arise in the night, clad only in his nightshirt, and carry his telescope tube to the spot. One night, a passing boatman saw Nasmyth wending his way through the trees and, apparently frightened by the apparition, spread the rumor that on certain starlit nights a ghost could be seen carrying its coffin along the river bank. Nasmyth's favored spot remained uncrowded.

More recently, members of the Pocatello (Idaho) Astronomical Society were surprised one evening by an alert deputy sheriff. The lawman noticed what appeared to be a battery of mortar tubes aligned on a hill overlooking Pocatello. After calling in the license numbers of the assorted vehicles parked nearby in the sagebrush, the officer blocked the access road with his cruiser and approached the unsuspecting group. His efforts weren't wasted. The intrepid deputy got his first look at Saturn and a minicourse in observational astronomy.

Nearly every observer has been involved in, or knows of, an interesting or humorous event that has occurred while observing the stars. Curious neighbors, animals, the weather, and a host of things have been responsible for some unusual observing sessions. I am compiling a collection of such anecdotes and would appreciate learning about any such experiences from readers of ASTRONOMY.

Gail O. Clark
74 Mountain Road
Pocatello, ID

Astronomical Weather Vane

Sir / When I first subscribed to ASTRONOMY a half-dozen years ago I was inspired by your "Star Dome" to learn about upcoming celestial events. Since I live in the city where the night sky is bright, I would note the dates of the more spectacular events so I could go out on those nights to observe. Invariably, though, the appointed night would be socked in with clouds.

The 1979 total eclipse of the Sun, for example, took place in fog so thick it was impossible to tell that the Sun had *risen*, let alone been eclipsed!

It got to the point where I was able to predict the weather — successfully.

"It's gonna rain Tuesday night," I'd say.

"How do you know?"

"Because there's this big meteor shower..."

One evening there was to be a conjunction of Venus with another planet. I had been watching the bright planet creep across the sky toward its rendezvous for several days. The big day dawned bright and clear, and as the day wore on, still cloudless, I began to hope. Then just half an hour before dusk a great wall of fog rose out of the sea, contemptuously blotting out just that portion of the sky where the planets were to meet, while the rest of the sky remained clear! The fog dissipated shortly after the planets set.

That did it. I know when I'm licked! Clearly someone up there does not want me to observe. And I had been looking forward to seeing Halley's Comet, too. Now you know why it didn't amount to much.

Nancy (the Jinx) Martsch
Los Angeles, CA

Weathermen Want Clear Skies, Too

Sir / I am an assistant professor of meteorology at Michigan State University, but occasionally I like to gaze a bit higher beyond the atmosphere. As an amateur astronomer in the crudest sense (I only own a pair of 8x35 binoculars), I had an exciting five-day span of observing August 8 to 12, thanks to your August issue.

Intrigued by the article on earthshine ("Some Reflections on Earthshine," Gazer's Gazette), I observed this phenomenon August 8 at around 9:30 p.m. EDT. Situated above the west-northwest horizon, the setting three-day-old crescent Moon was indeed dimly illuminated on its dark side, so that the entire disk could be seen.

The letter from Peter Wilson (In Focus, August 1986) regarding viewing Venus by day took me by surprise, so I decided to try it. Sure enough, on the afternoon of August 9 I was able to spot Venus in broad daylight about six Moon-diameters to the west-northwest of the crescent Moon. I found it best to search for Venus with binoculars first. Once you know where to look, it's much easier with the naked eye.

My next event occurred August 11 at about 6 a.m. when I was able to observe Mercury in the east-northeast in morning twilight. The crescent shape could be clearly seen.

The finale occurred between 12:30 and 1:30 a.m. on August 12. The event was the Perseid meteor shower. We had excellent seeing over Michigan with a dome of cool high pressure from Canada overhead. During this hour of chilly observing I was able to spot thirteen meteors, most radiating from Perseus. They were very swift: some had long trails, others short. Some of the trails were orange and yellow, but most were white.

This all goes to prove that weathermen can't be all bad — some of us want clear skies, too!

J.D. Carlson
East Lansing, MI

Viewing Conditions in Colorado

Sir / The right spot and a clear Rocky Mountain night is fantastic for stargazing. I have found one such area near Gold Hill, about thirty-five minutes into the mountains west of Boulder.

The elevation there is nearly 9,000 feet above sea level. Although Denver's lights are visible on the distant plain, they are confined to an area far below my vantage point. Above, the sky is very dark — no smog, no haze — just beautiful black space and brilliant stars.

I was picking out 13th-magnitude galaxies with ease using my 8-inch f/4.5 Dobsonian reflector. Several of the dimmer planetary nebulae also fell prey to the high powers I was able to employ. At lower elevations (around 5,000 feet), my scope usually peaks out on extended objects at around 240x, but on this night I was able to push it up over 300x with no problems.

At 48x (19mm wide field), M-31 was a whopping three fields of view from edge to edge. The Whirlpool Galaxy showed fine detail in the two large spiral arms and, for the first time, I saw the arm that connects it with the smaller companion. The Veil Nebula was heart-stopping. And the Lagoon Nebula was a sprawling mass of gas and dust that filled the eyepiece at low power.

This is what astronomy is all about.

Tom Johnston
Boulder, CO

Oops!

The U.S. Naval Observatory's astronomy advice "hotline" (AstroNews, September 1986) is available only on the seven days following the first Sunday of each month. At the present time, this service is not active during the rest of the month.

Behind the Scenes

Looking Back at Hale

In this issue of ASTRONOMY we look back to the age when astronomy was sponsored largely by private donations, to the age when a single man, George Ellery Hale, masterminded the funding and construction of 60- and 100-inch telescopes on Mount Wilson. In a sense, this December's feature is a continuation of a story that ran in the December 1982 issue of ASTRONOMY about Hale and the founding of the Yerkes Observatory.

Underlying the exuberance in the present tale, though, is a feeling of loss, for the great instrument atop Mount Wilson that Hale worked so long and hard for has been shut down and put in "mothballs."

One can hardly fault the Observatory and the Carnegie Institution for wanting to employ their resources in the most effective possible way — and, after all, it is their telescope to do with as they please. Hale would have leapt at the chance to build an 8-meter telescope in the Southern Hemisphere. In fact, for years he petitioned the Carnegie Institution for a southern 60-inch. I suspect that he would even have sacrificed a 100-inch (2.5-meter aperture) instrument at a site with bad light pollution for a much larger one under dark southern skies.

But the 100-inch need not be sacrificed. For stellar spectroscopy the old telescope is still virtually unsurpassed. And the Carnegie Institution says that it is looking for an "operator," someone with funds to continue scientific research using it. I hope that within a few years you will read a story in AstroNews announcing that the 100-inch has just begun its second career.

Since World War II American science has been heavily funded by the federal government, so much so that private funding is the exception rather than the rule. But this may be changing, at least a little. In this month's second Forum story, starting on page 28, I tell how a small astronomy department at a relatively small state university hopes to fund new research positions. One of the most interesting aspects of the story is the possibility of closer ties between professional and amateur astronomy. It would serve both communities well.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

Photography in Astronomy

In Search of Dark Nebulae

by Robert Reeves

Most backyard astrophotographers spend their telescope time taking pictures of the sky's great showpieces, like the Orion Nebula, the Andromeda Galaxy, or the Lagoon Nebula. In the past I've followed this course, snapping portraits of bright objects. Why? Because I'd seen the pictures other photographers have taken of those same objects and I wanted to gauge my success.

Recently, though, I've started to take photographs of a very different class of deep-sky object — dark nebulae. The Milky Way is loaded with dark patches, places that seem to contain nothing but blackness. In the mid-eighteenth century the British astronomer Sir William Herschel dubbed these areas "holes in the heavens." These holes are actually clouds of dust that block light from passing through. They are visible only as obscuring dark patches silhouetted against bright objects in the background.

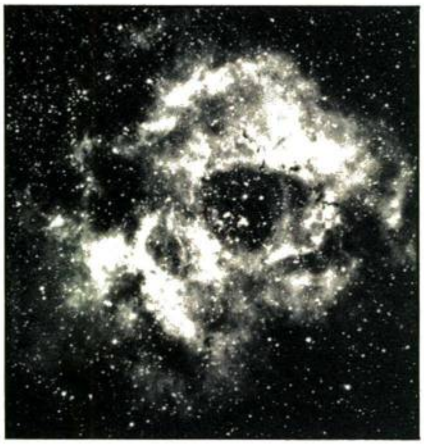
Edward Emerson Barnard, an American pioneer in astrophotography, was the first to discover many large dark nebulae when he began systematically photographing the Milky Way in 1889. At first Barnard thought the dark patches were areas that simply contained no stars, but by 1919 he had deduced their true nature.

In 1927 Barnard's photographic studies produced a book of handmade photographic prints called *An Atlas of Selected Regions of the Milky Way*, a classic work that is still studied by astronomers. In the atlas Barnard included his notes on 349 dark nebulae he had identified and catalogued, creating the counterpart to the Messier catalogue of bright objects — the Barnard catalogue of dark nebulae.

The relative visibility of a dark nebula is dependent on its opacity, that is, the degree to which it blocks light. The most opaque nebulae are visible in backyard telescopes on dark, moonless nights. Most of Barnard's objects can be photographed with backyard scopes, providing you follow the guidelines discussed below.

Bok globules are a special type of dark nebula — very small, roundish, dark patches visible only with long focal-length instruments on exceedingly dark nights. These opaque knots of dust are gravitationally compressed and are expected to produce stars. Globules are more difficult to photograph than most dark nebulae, but some areas of Bok globules, such as the one entangled in the Lagoon Nebula, can be recorded with relative ease.

How can you photograph dark nebulae? First, be prepared to make long exposures of the areas you wish to photograph. The exposure time depends a bit on sky brightness, film, and the focal ratio of your instrument, but generally you must be willing to guide 20-minute, 30-minute, and even 40-minute exposures. This may sound like a long time to expose your film without the overall sky light fogging it completely, but you can avoid this by using a hydrogen-alpha (Hα) filter in front of the camera's lens or between the telescope and camera. This dense, red filter increases the contrast between bright and dark objects and allows you to expose film for very long periods.



Dark lanes and Bok globules abound in the Rosette Nebula. All photos in this article, unless otherwise indicated, are by Robert Reeves.

A second way to maximize success is using Tech Pan film, an extremely fine-grained emulsion that works well with an Hα filter. It is relatively slow, but hypersensitizing effectively speeds up the film to a point where it's useful for astronomical exposures. For specific how-to information on handling and developing Tech Pan film, see "Photography in Astronomy" in the April 1981, May 1981, and March 1982 issues of ASTRONOMY.

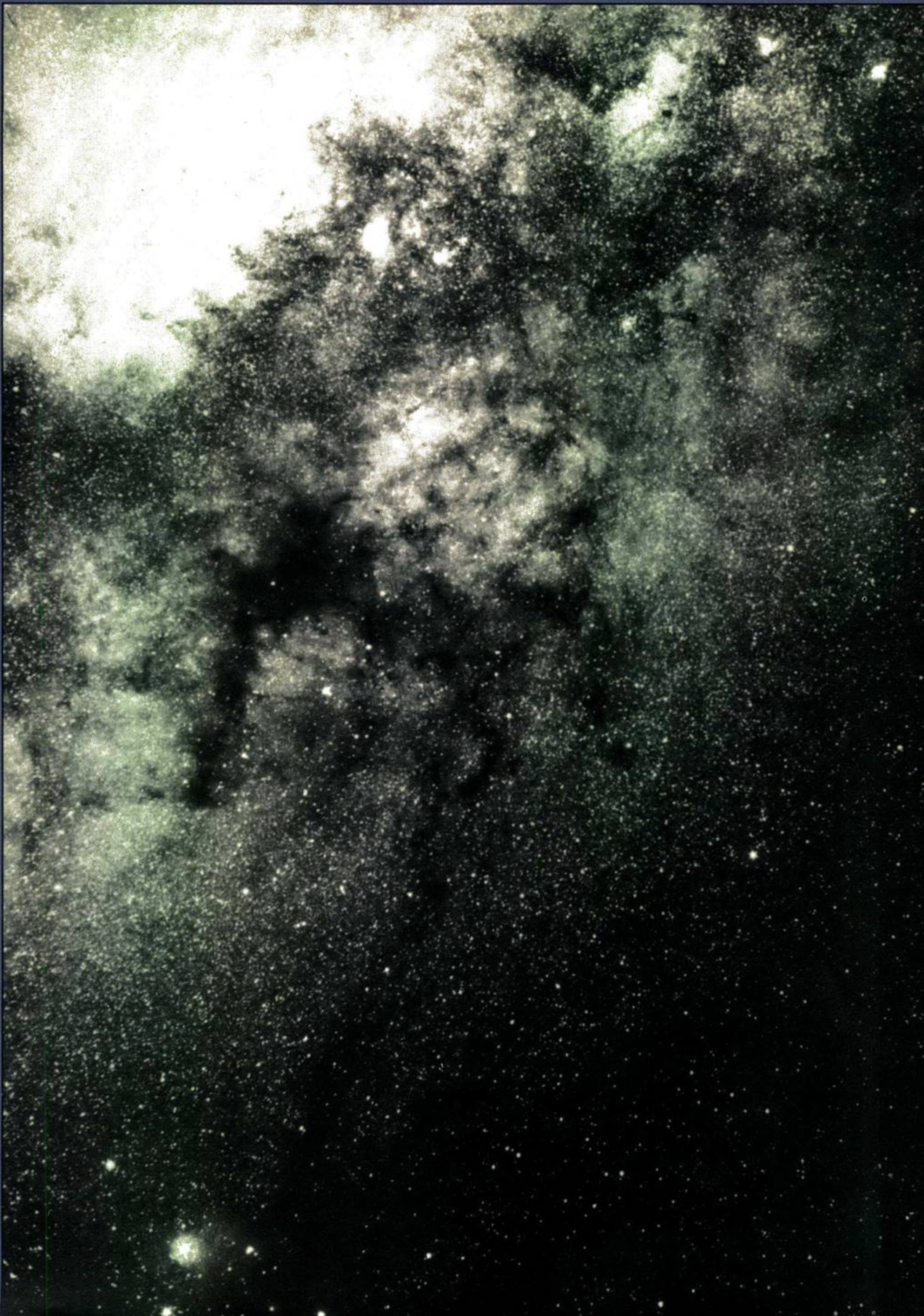
The appropriate focal length of your lens will depend on the type of dark nebula you want to photograph. One possibility is a standard 50mm or even a 28mm wide-angle lens which will capture the dark patches that line the Milky Way's edges. Or you can photograph small sections of dark nebulosity in objects like the Rosette Nebula in Monoceros or the Lagoon Nebula in Sagittarius. But the most practical focal length for shooting dark nebulae lies somewhere between 85mm and 200mm, which means a sharp, fast telephoto lens may be the best choice. Used with fine-grain film a telephoto lens will record exquisite detail in dark nebulae and cover enough sky to include even the largest dark nebula.

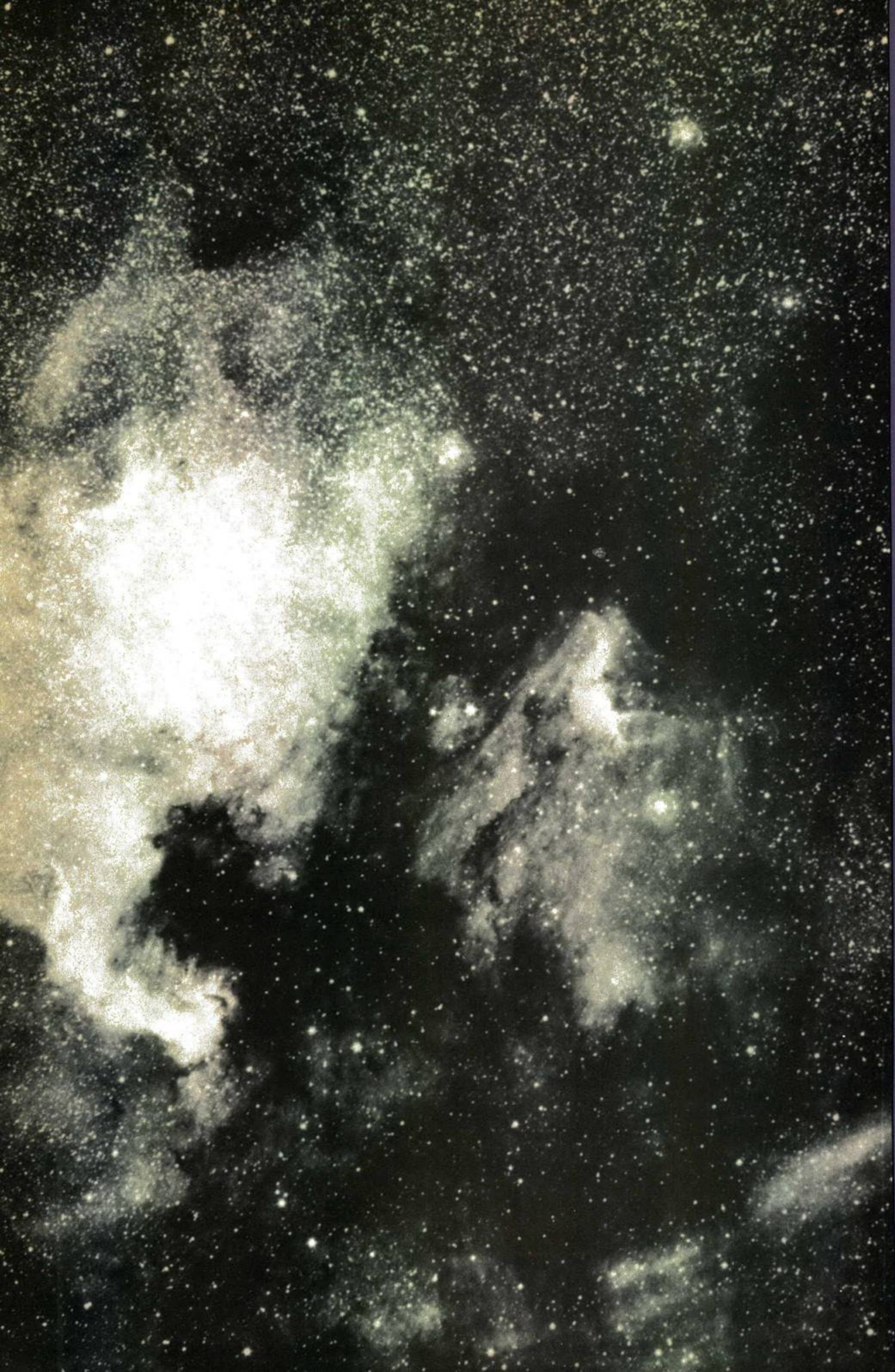
Suppose you want to photograph a selection of dark nebulae. Which are the best?

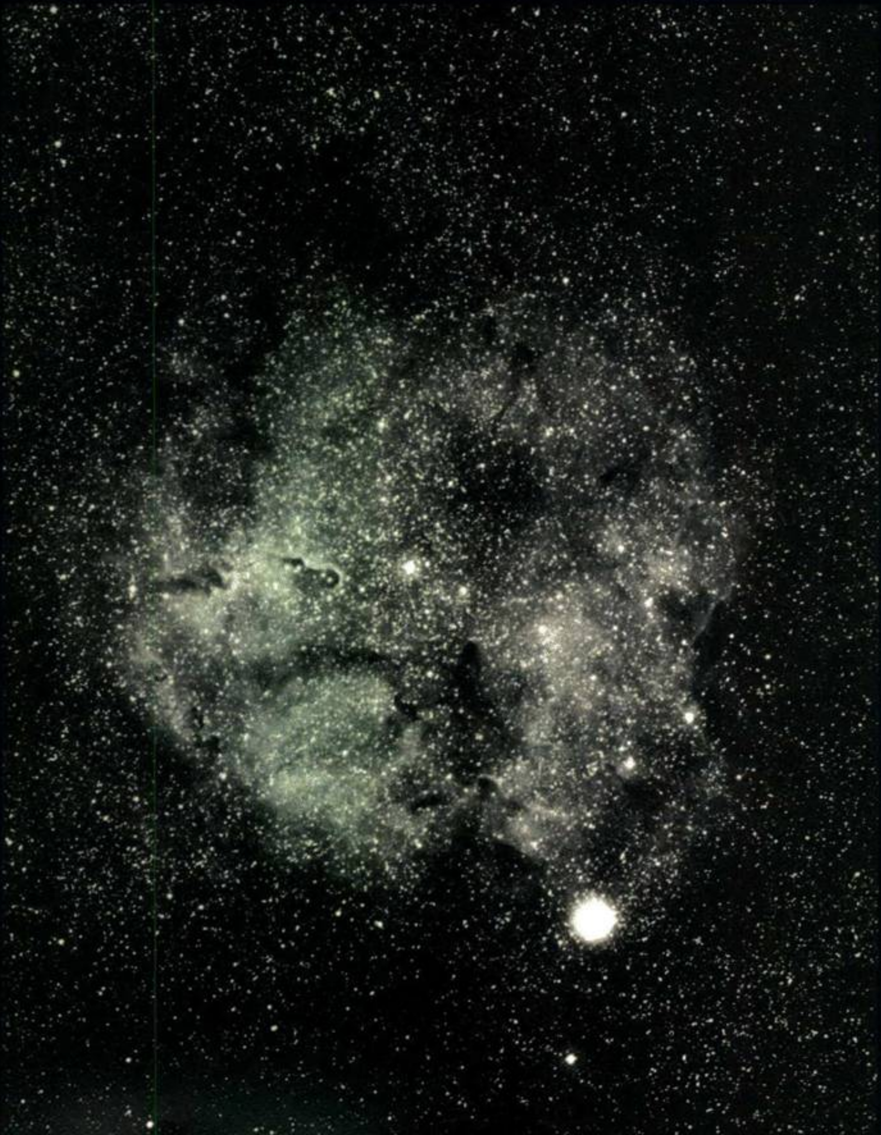
One of the most popular dark nebulae is also one of the smallest: Barnard 33, the Horsehead Nebula in Orion. Found between the magnitude 1.8 star Zeta (ζ) Orionis and two 6th-magnitude stars to the south, the Horsehead is notoriously difficult to see and is only about 3′ across. The dark patch is backlit by the dim emission nebula IC 434, a strip of nebulosity excited to ionization by the hot star Sigma (σ) Orionis.

An impressive nebula visible in the winter and riddled with tiny dark nebulae and Bok globules is the wreath-shaped Rosette Nebula in Monoceros. This object is easy to find since it forms a right triangle with the 5th-magnitude stars Epsilon (ε) and 13 Monocerotis. The Rosette measures a whopping 80′ by 60′ across

Lying amid the bright Milky Way in Ophiuchus, the "Great Galactic Dark Horse" is a network of dark nebulae some 15° across. Antares lies at lower left; the Lagoon and Trifid nebulae at upper left. Photo by Alan Sifford.





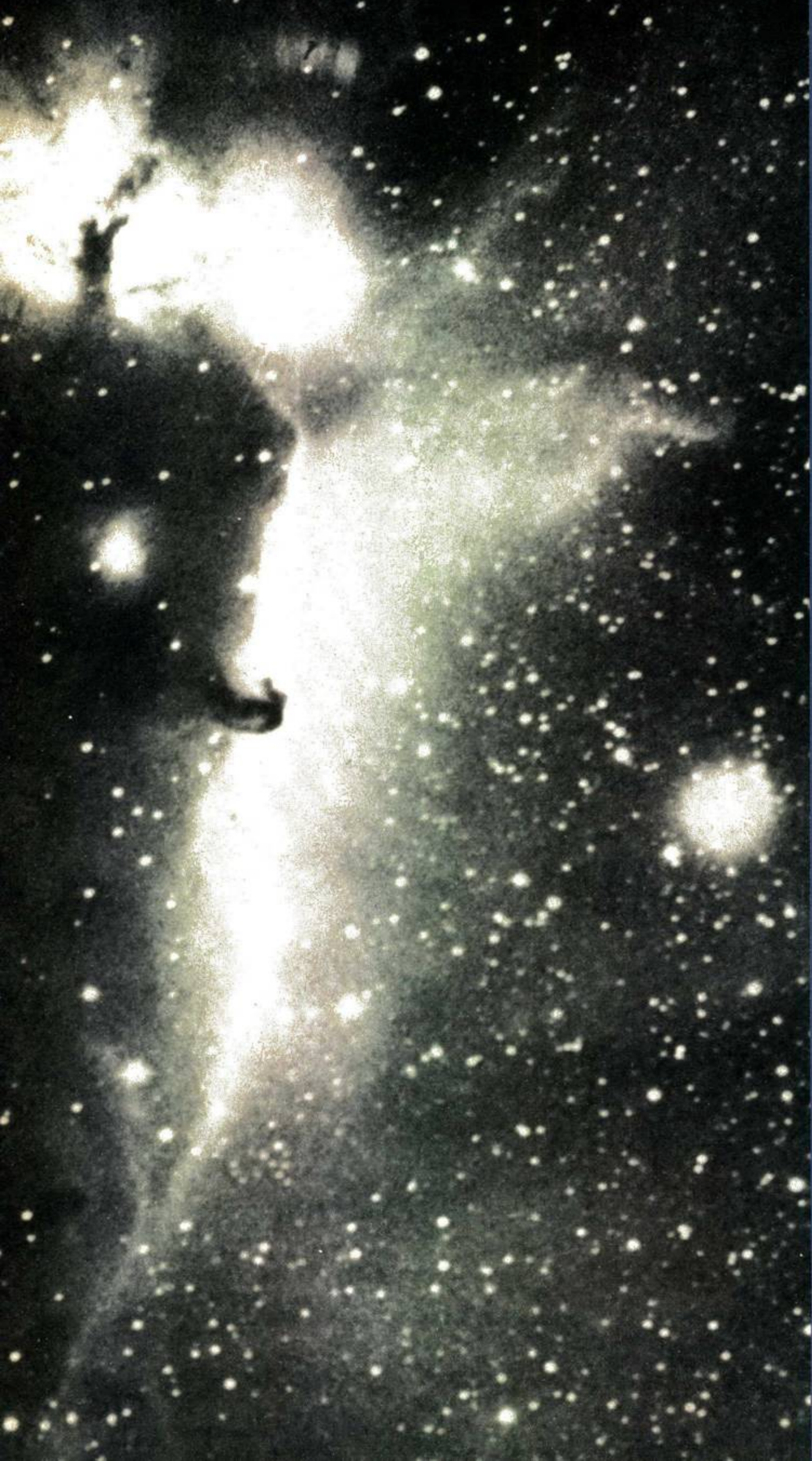


Above: Dark nebulae Barnard 142 and 143, shaped like a letter "E," can be easily photographed against the rich starfields in Aquila. Toward the left edge lies the 1st-magnitude star Altair.

Left: The enormous complex of emission nebulosity known as IC 1396 is laced with *intricate dark nebulosity. At its bottom* right is the star Mu (μ) Cephei, the ruddy "Garnet star."

Opposite page: One of the finest regions of contrasting bright and dark nebulosity is that of the North America and Pelican nebulae in Cygnus.

Photos by Robert Reeves.



Backlit by the strip of nebulosity called IC 434, the Horsehead Nebula in Orion is the archetypal dark nebula. It can even be photographed with a 50mm lens with a long exposure time. Photo by Robert Reeves.

— more than two Moon diameters! A faint object for large backyard telescopes, this nebula is easily photographed and, if you use a telephoto lens or a telescope, you'll record plenty of dark nebulosity intertwined with the bright gas.

In Cepheus, only 30° away from the North Celestial Pole, lies the gigantic nebula IC 1396. At 170′ by 140′ in diameter, it is one of the largest nebulae in the sky. Like the Rosette, IC 1396 is exceedingly faint to the eye but can be photographed quite easily under a dark sky. This nebula is surrounded by broad dark lanes and is laced with dark nebulosity that shows up well against the bright nebulosity in the background.

Cygnus contains two grand regions of dark nebulosity that are easily captured on film. The region around the magnitude 2.2 star Gamma (γ) Cygni holds a ring of bright nebulae collectively dubbed IC 1318. This large complex of gas and dust appears to be separate sections due to intervening dust clouds. Even a 10- or 15-minute exposure of this area under a dark sky should show some of this magnificent dark nebulosity.

Another fine spot in Cygnus is the North America Nebula, a great nebulosity roughly shaped like the continent of North America. On dark nights it is visible to the naked eye as a hazy circular patch of light. Dark nebulae abound in this region; a 50mm lens shot will reveal the "Gulf of Mexico," the band of dark nebulosity most prominent in the area.

As you pursue astrophotographic subjects this winter and spring, don't just think of overphotographed objects like the Orion Nebula and the Andromeda Galaxy. There's an entire universe of objects waiting to be recorded on film, and dark nebulae — a class not often considered by backyard photographers — bring a new dimension to amateur astrophotography.

Robert Reeves is an astrophotographer and telescope maker living in San Antonio, Texas. His last article was "Hurrah for the Northern Sky!" in the November 1985 issue.

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Meade 2080/GEM,	as above, but with multi-coated silver optics (MCSO), *$\$2350^{00}$ list*	$\$1295^{00}$
Meade #784 quartz drive,	for 2080/Gem series, *$\$310^{00}$ list*	$\$199^{50}$
Meade 2080/LX3	8" Schmidt-Cassegrain, wedge, tripod, quartz AC/DC drive, *$\$3100^{00}$ list*	$\$1695^{00}$
Meade 2080/LX3,	as above, but with multi-coated silver optics (MCSO), *$\$3320^{00}$ list*	$\$1795^{00}$
Meade 2120/LX3	10" version of 2080/LX3, includes MCSO, *$\$5390^{00}$ list*	$\$2795^{00}$

Model 6600, right, shown with all standard accessories.

~~$\$1400^{00}$~~ **$699**

Meade 320	3.1" refractor, adjustable tripod, slow motion controls, two eyepieces, *$\$1200^{00}$ list*	$\$599^{00}$
Meade 6600	6" f/5 reflector, adjustable height tripod, slow motion controls, two eyepieces, *$\$1400^{00}$ list*	$\$699^{00}$
Meade 8800	8" f/5 reflector, adjustable height tripod, slow motion controls, two eyepieces, *$\$1800^{00}$ list*	$\$899^{00}$
Meade #784 quartz drive,	for 320/6600/8800, *$\$310^{00}$ list*	$\$199^{50}$
Meade 622	6" f/3.6 Schmidt-Newtonian wide field reflector, eyepiece, tripod adapter, *$\$900^{00}$ list*	$\$499^{00}$
Meade 628C	6" f/8 reflector, mount, drive, 8 x 50mm finder, two eyepieces, *$\$1500^{00}$ list*	$\$799^{00}$
Meade 645C	6" f/5 reflector, mount, drive, 8 x 50mm finder, two eyepieces, *$\$1520^{00}$ list*	$\$829^{00}$
Meade 826C	8" f/6 reflector, mount, drive, 8 x 50mm finder, two eyepieces, *$\$1640^{00}$ list*	$\$949^{00}$
Meade DS-10	10" f/4.5 reflector, pedestal mount, 25mm eyepiece, *$\$1400^{00}$ list*	$\$849^{00}$
Meade DS-10A,	as above, but with setting circles and motor drive, *$\$1600^{00}$ list*	$\$979^{00}$
Meade DS-16A	16" f/4.5 reflector, mount, drive, eyepiece, shipped freight collect, *$\$3140^{00}$ list*	$\$1895^{00}$

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LUMICON FOR HIGH PERFORMANCE

ASTROPHOTO OF THE MONTH

The Double Cluster NGC 869 & 884 in Perseus. Photo by Martin Germano using an 8" f/5 Newtonian telescope, 15 minute exposure, 103a-F film. Mr. Germano used a LUMICON Newtonian EASY-GUIDER and LUMICON 2" Helical focuser to facilitate focus and guiding.

20mm NAGLER

New 2" eyepiece with 82° field $295

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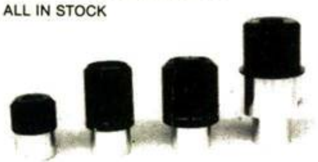


Renaissance 4" f/5.5. Telescope	$1395
7.4, 10.4, 13, 17, 21, 26mm Plossl, 50°	**$95**
1.8X or 2.5X Tele Vue Barlow Lens	**$95**
32mm Plossl, widest true field in 1¼"	**$110**
55mm 2" Plossl, widest possible field	**$190**
15mm Wide-Field, 1¼" eyepiece, 65°	**$130**
19mm Wide-Field, 1¼" eyepiece, 85°	**$145**
24mm Wide-Field, "superb," 65°	**$160**
32mm Wide-Field, 2" eyepiece, 65°	**$230**
40mm Wide-Field, "awesome," 65°	**$295**
4.8mm Nagler, 82° field	**$150**
7mm Nagler, 1¼" eyepiece, 82° field	**$185**
9mm Nagler, 82° field, "the best"	**$225**
11mm Nagler, 82° field, 1¼" or 2"	**$240**
13mm Nagler, 82° field, 1¼" or 2"	**$250**
20mm Nagler, 82° field, 2" eyepiece	**$295**

48mm COLORED FILTERS

Upgrade to 48mm filters! All are multicoated

UV, Green, Yellow, Orange, Red	**$18 each**
48mm H-Alpha Pass (640nm cut-off)	**$35**
48mm Minus Violet (420nm cut-off)	**$29**
48mm High perform blue, 90% trans	**$35**
Central Star Filter (blue tri-color) 340-470nm bandpass	**$35**
UV-370 U-Band, 320-420nm bandpass	**$35**
48mm Polarizer (2 make variable density)	**$18**
Set 9 ea. 48mm filters ($259 list)	**$195**
2"/1¼" adapter threaded for 48mm filters	**$20**

H-ALPHA PASS FILTER

Yields spectacular contrast gains in B&W photography with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) Filter.

Specify Lens Size	**H-Alpha**	**(MV)**
46, 48, 49mm	**$35.00**	**$29.00**
52, 55, 58, 62mm	**$45.00**	**$35.00**
67, 72, 77mm	**$52.00**	**$45.00**
82mm	**$55.00**	

Hypered 2415 film, 36 exp . . . **$10.95** . . . **3/$29**

NEW! ENHANCED SILVER DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

LUMICON 1.3" & 3.1" enhanced silver diagonal mirrors & 2" star diagonal.
The new LUMICON diagonal mirrors have a special enhanced silver coating with a protective overcoating for long life. Visible reflectivity is 98-99% compared to 86-89% for standard aluminum coated mirrors. The extra 10-12% transmission is like adding an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32"	**$29.95**	1.52"	**$34.50**	1.83"	**$39.50**
2.14"	**$49.50**	2.60"	**$65.00**	3.10"	**$89.50**
4.25"	**$149.50**				

ENHANCED SILVER STAR DIAGONAL

90° star diagonals with above enhanced silver mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

1¼" (1.32" mirror)	**$89.50**
2" (1.83" mirror)(see photo above)	**$145.00**

LUMICON FILTERS STOP LIGHT POLLUTION

UHC Filter™

ULTRA HIGH CONTRAST

The **LUMICON UHC FILTER** is specially designed for visual astronomy in areas of severe light pollution or for viewing very faint nebulae at any location. **UHC** stands for **U**ltra **H**igh **C**ontrast and this filter is guaranteed to yield a higher visual contrast on planetary and emission nebulae than any other filter at any price. 24nm visible bandpass, 482-506nm. Transmission = 85-95%.

"I CAN SEE THE VEIL NEBULA!"
Rich Zepernick saw the Veil Nebula for the very first time with a LUMICON UHC Filter. He stated, "*It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters.*"
Zepernick, Cresskill, NJ

For optimum astronomy, use either the **LUMICON DEEP-SKY Filter** or the **LUMICON UHC Filter**

DEEP-SKY FILTER™

The **LUMICON DEEP-SKY FILTER** improves your view of **all** deep-sky objects including galaxies and comets. It removes natural and man-made light pollution and yields 3-6x contrast gain for nebulae and 1-3x contrast gain for clusters and galaxies. It is ideal for **both** visual use and B&W or color photography. This gentle filter yields the most natural view of any LPR filter available today. 90nm visible bandpass. 442-532nm. H-Alpha 656nm transmission = 80-95%.

	Standard	**Premium***
1¼" **LUMICON DEEP-SKY Filter** threads into most 1¼" eyepieces		**$79.50**
48mm LUMICON DEEP-SKY Filter (1.75" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS		**$119.50**
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	**$99.50**	**$119.50**
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $8)		**$299.50**
1¼" **LUMICON UHC Filter** threads into most 1¼" eyepieces	**$79.50**	**$99.50**
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	**$159.50**	**$199.50**
Set of Both 1¼" **DEEP-SKY** and **UHC Filters** (Save 11%)		**$159.50**
1¼" **H-BETA Line Filter** 9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae)		**$89.50**
48mm "Horsehead Nebula" H-BETA Line Filter		**$189.50**
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm 0-III lines		**1¼" $99.50, 48mm $199.50**
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm		**$6.95**
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece		**$16.00**
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece		**$20.00**

**Premium filters are selected best of the lot and typically have 5-10% higher transmission. Not always available. Include individually measured transmission data.*

DEEP-SKY ASTROPHOTOGRAPHY

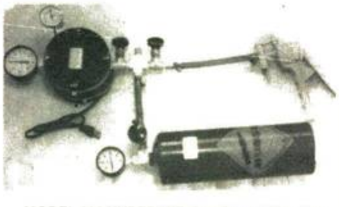
FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15X film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

†U.S. Patent 4,473,636

MAKE YOUR OWN HYPERED FILM

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$295.00**



MODEL 600 HYPER-KIT [See Photo] Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$350.00**

MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller . . **$595.00**

Temperature controller for any HYPER-KIT **$59.50**

Electric Vacuum Pump, Model R-10 **$280.00**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X eaiser guide-star selection, use 48mm filters, 360° camera rotation, large prisms fo bright guide-starts. *Specify Camera and Telescope type.*
U.S. Patent # 4,448,500

NEWTONIAN EASY-GUIDER™

Full aperature. Installs in secs. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER	**$169.50**
3X Relay Diagonal (see photo)	**$79.50**
Illuminated reticle eyepiece system	**$79.50**

Guider for Hasselblad **$350,** Mamaya 645 **$159**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Dynamax-8. Includes 50mm achromatic lens for f/5.8 operation-3X shorter exposures! **Superb rich field viewing, too!**

CASSEGRAIN EASY-GUIDER **$225.00**
Adapter for Hasselblad **$185,** Mamaya 645 **$159**

GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER **$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20) . . . . . . **add $99.95**
Adapter for Hasselblad **$195,** Mamaya 645, **$96**

WHAT DO YOU NEED?

1. **Illuminated reticle eyepiece** . . . $79.50
Lumicon 12mm eyepiece system has adjustible L.E.D. illumiation, dual crosslines, battery pack.
2. Cable release for long exposures . **$9.95**

3. **LUMICON Quartz Drive Corrector $219**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 40Hz/80Hz variable output controls telescope drive. 60Hz Quartz reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Declination reverse switch for Newtonians.
Declination motor (state telescope) . . **$70**
NEW Deluxe Digital Qtz. Drive Correc. **$298**

HYPERSENSITIZED FILM

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.).

Film Type, 35mm	**Exposures**	**Price**
2415, Ultra-fine B&W, red sens.	36	**$10.95**
SR1600, fastest of all, color neg	24	**$12.95**
Konica SR200, fine grain color neg	12	**$9.95**
3M 1000, fastest slide film	20	**$12.95**
Fujichrome RD100, fine grain slide	24	**$12.95**
5072, color slides from neg	36	**$6.95**
D-19 B&W Developer	1 gal.	**$6.95**

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Meade® TELESCOPES AT LUMICON

MEADE 2080/LX3 w/MCSO $1685

#712 Dew shield (8") and accessory tray ($140 list)	**add $89**

MEADE 2120/LX3 w/MCSO $2590

Accessory shelf for field tripod ($40 list)	**$32**
#710 dew shield (10") Essential! ($140 list)	**$98**
#36 dual-axis drive corrector control box ($150 list)	**$99**
#38 declination motor and clutch ($150 list)	**$99**
LUMICON Giant EASY-GUIDER/Rich-Field viewer for f/4-f/10 operation (state camera)	**$395**

2080/LX3
$1685
2080/LX3
W/MCSO

NEW! Quartz Drive Meade 2080/LX3

The Meade 2080/LX3 with built-in quartz electronic drive system is positively the highest performance 8" Schmidt-Cassegrain telescope system available today.

2120/LX3 10'' System w/MCSO $2590

The 10" Meade 2120/LX3 collects 56% more light than an 8" telescope for significantly improved viewing and astrophotography. It has all the features of the 2080/LX3 (see Meade ads in this magazine for full list of features.)

4'' MEADE 2045 w/table tripod $695

NEW! Meade 2045/LX3 w/quartz drive	**$885**

IN STOCK!
NEW!
2045/LX3

Meade Model 2045 — Advanced engineering and superb optical performance in a beautiful ultraportable system.

FEATURES OF THE MEADE 2045

- ★ 4" f/10 Schmidt-Cassegrain optics, F=1000mm
- ★ Motor drive for automatic tracking, 110 VAC input
- ★ **LX3:** quartz-controlled elec. drive, 12VDC or 110VAC input
- ★ High transmission coatings on front corrector lens
- ★ Table tripod for easy polar alignment
- ★ 5X24 finderscope & 1¼" right-angle star diagonal
- ★ 1¼" 25mm (40X) and 9mm (111X) eyepieces
- ★ Fork mount with setting circles, manual slow motion

HIGHLY RECOMMENDED OPTIONS

Model 43 drive corrector uses 12VDC ($120 list)	**$96**
See Meade 2080/LX3 options	
Wedge & field tripod for Meade 2045 ($380 list)	**$298**
Dew shield ($70) .... **$49** Solar Filter ($180)	**$139**

TELESCOPE SALE

Meade
THE LEADER'S EDGE
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ONLY
$698!

Meade Model 628 6" f/8 **w/motor,** 1¼" focuser, 6X30mm finder ($1226 list)	**$698**
Meade Model 628C 6" f/8 **w/motor,** 2" focuser, 8X50mm finder ($1450 list)	**$798**
Celestron-11 with Starbright coatings	**$3250**
Celestron Super Polaris SP-C8, 8" f/10 on equatorial mount w/high transmission coatings ($1950 list)	**$1095**
Celestron CO-114, 4½" f/9 reflector & mount	**$425**
Meade Model 310, 80mm f/11 refractor ($800 list)	**$449**
Meade Model 107-D 4" f/10 spotting scope	**$429**

NEW! 2080/GEM and 2120/GEM

Schmidt-Cassegrain Optics on German Equatorial Mount

2080/GEM, 8" f/10 w/equatorial mount ($2100 list)	**$1099**
Multi-coated silvered optics, boost transmission 18%	**add $149**
2120/GEM, 10" f/10 w/equatorial mount **and with multi-coated silvered optics** ($4300 list)	**$2195**
Dew shield & accessory tray, 8" .... **$72** 10"	**$144**
#785 motor and quartz drive correc. system ($270 list)	**$198**
#3000 computer control system ($1500 list)	**add $949**

The Meade 2080/GEM and 2120/GEM telescopes include the same diffraction limited optics as the 2080/2120/LX3. Large, stable German equatorial mount with setting circles, slow motion controls on both axes, large 8X50mm finderscope, 25mm 1¼" eyepiece, integrated polar alignment scope, and heavy duty adjustable height tripod (hardwood for 2080, metal for 2120). The computer control provides automatic object location from an extensive software library of deep-sky objects.

OPTIONS BOOST PERFORMANCE

LUMICON UHC Filter for nebulae. Standard 1¼"	**$79**
Prem 1¼", **$99;** Std 48mm, **$159.50;** Prem 48mm,	**$199.50**
LUMICON Deep-Sky Filter, 1¼" Premium	**$79**
48mm Prem Deep-Sky ..... **$119.50, $99.95** w/Easy-Guider	
Adapter for viewing w/1¼" eyepiece	**$20**
Dust covers. Keep optics clean. For 6"	**$16/pair**
8" .... **$20/pair;** 10" .... **$18;** 16"	**$24**
LUMICON Rich-Field Viewer (2080)	**$140**
LUMICON Newtonian Easy-Guider, 1¼" or 2"	**$169**
#122 2X Barlow ($60 list)	**$48**
Dual-axis drive corr. and elec. dec. for 2080/LX2	**$298**
for model 628, 826, DS-10 .... **$340** for DS-16	**$440**
Tele Vue 32mm Plossl 1¼" eyepiece	**add $99**
LUMICON Cassegrain EASY-GUIDER for Meade 2045, 2080/LX3 and 2080/GEM (state camera)	**$225**
Illuminated reticle eyepiece & battery pack	**$79.50**

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8'' f/6 NEWTONIAN.........$995

SALE

$698
(Model 628)

$798
(Model 628C)
6'' f/8 with
motor drive

Model 826, 8'' f/6 Telescope w/accessories

Model 628, 6" f/8 with motor drive ($1220 list)	**$698**
Model 628C, 628 w/2" focuser, 8x50mm finder ($1450	**$798**
Model 826C, 8" f/6 with motor drive, #680 2" focuser and 8x50mm finderscope ($1590 list)	**$995**

—Collects 78% more light than a 6" telescope.

These Meade Deluxe Series reflecting Telescopes have superb image quality at low or high power. They include an equatorial mount with motor drive, pier, legs, setting circles, 2" rack & pinion focuser, 8X50 finderscope (628C & 826C only), 25mm (48X) and 9mm (135X) 1¼" eyepieces, altitude and azimuth fine adjustments for polar alignment.

#43 drive corrector uses 12VDC ($120 list)	**$96**
#47M Dual-axis drive corrector & elec. dec.	**$340**
1¼" or 2" EASY-GUIDER (state camera)	**$169**

6'' f/5 NEWTONIAN........$695

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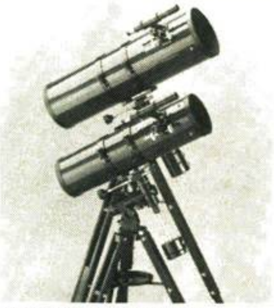
AVAILABLE
AT 1985
PRICES!



Models 6600 (6" f/5) & **8800** (8" f/4.5) telescopes

Model 6600, 6" f/5 Newtonian telescopes ($1300 list)	**$695**
—Best performance & value; bright, wide views.	
Model 8800, 8" f/4.5 Newtonian Telescopes ($1700)	**$895**
—Collects 78% more light than a 6" telescope.	

These Meade Professional Series reflecting telescopes yield superb rich-field viewing w/bright images. They include an equatorial mount w/adjustable tripod, setting circles, slow motion controls, 6x30mm view-finder, 1¼" focuser, 25mm & 9mm 1¼" eyepieces & accessory tray.

#784 motor & quartz drive corrector ($270 list)	**$198**
Basic camera adapter (for moon & planets)	**$32**
1¼" LUMICON Easy-Guider (state camera)	**$169**

16'' f/4.5 NEWTONIAN......$1995

STILL
AVAILABLE
AT 1985
PRICES!

Meade DS-16A with Accessories

The DS Series of 10" and 16" reflecting telescopes are ideal for deep-sky viewing and photography.

DS-10A, 10" f/4.5 with motor drive ($1600 list)	**$995**
—Gathers 56% more light than an 8" telescope	
DS-16A, 16" f/4.5 with motor drive ($3140 list)	**$1995**
Sealmaster ball bearings, highly recommended	**add $229**
—Gathers 400% more light than an 8" telescope	

Both the DS-10A and DS-16A telescopes include an equatorial mount, #680 2" focuser, motor drive, setting circles and 25mm 1¼" eyepieces. The DS-10A is shipped freight collect.

6x30mm finderscope with brackets ($56 list)	**$42**
8x50mm finderscope with brackets ($130 list)	**$96**

ASTRONOMY
Reviews

Contact
Carl Sagan
434 pages, paper, $4.95
Pocket Books (1986)

In the not-too-distant future, the world suddenly discovers that aliens from another star have . . .

No, this is not the story line of *Contact*, but of another novel about man's encounter with aliens — *Puppetmasters* by Robert Heinlein. There is no heavy, hanging-by-one's-toenails drama in Carl Sagan's novel. Sagan is trying for a matter-of-fact tone that will convince readers by its very ordinariness. Although some of the events in this chronicle of mankind's first encounter with aliens may produce anxiety in the reader and in the main characters, the purpose of the book is to inform and show what first contact may be like.

To achieve conviction through description, an author has to build a tight world that will drag readers in by the sheer power of detail. Sagan does not make this method work in *Contact*. He cannot resist leaving his world for mini-essays — one example is a careful explanation of pi. He spends much time discussing religion in a manner which seems aimed at convincing religious people not to be afraid of scientists.

Sagan's development of the heroine also suffers from a lack of consistency and realism. She seems a nice enough young woman — intelligent and up to date — but you can feel Sagan's hand shoving her around. In successive paragraphs we are told that she is in serious danger of becoming a man-hater, and that "at a time when many of her contemporaries were moving toward shapeless clothing that minimized the distinctions between the sexes, she aspired to an elegance and simplicity in dress and makeup that strained her limited budget." These two traits in one person are not impossible, but juxtaposed here they tend to strain one's credulity.

The aliens, for most of the book, are quite likeable. They seem to have their first-contact routine well thought-out; they know how to give humans enough information to stimulate rather than scare them. But in spite of the heroine's unwavering faith in their good will, the aliens seem to play a dirty trick on her and her cohorts when, near the end of the novel, they act in a way that encourages people to think she has perpetrated an elaborate and nasty hoax. The idea that the aliens might not be acting totally aboveboard is even suggested to the heroine but she shrugs off the idea without even considering it.

For a first attempt in a new area, *Contact* is not bad, however. But other novels have been written on this subject that are more cohesive, exciting, and downright interesting. To learn about the fun of first contact, read one of those instead. *S. A. Blom.*

Supernovae
Paul and Lesley Murdin
185 pages, cloth, $24.95
Cambridge University Press (1985)

Every astronomer must spend his career half-waiting for the other shoe to drop.

In the 375 or so years since the invention of the telescope, the Galaxy has yet to present us with a supernova visible from Earth. Yet in the forty years before Galileo aimed his *perspicillium* skyward, there were two bright supernovae, one in 1572 and another in 1604! The next one seems to be long overdue.

To ease their frustration, astronomers juggle statistics drawn from observations of supernovae in other galaxies and prove, at least to their own satisfaction, that this delay is about what we should expect. A decade ago it looked like The Big One had finally come, but Nova Cygni 1975 was just that — an ordinary nova — unusually bright for its type, but no big deal, really.

Yet in a sense, we can be glad the next supernova has held off this long, for now several nonoptical observatories are orbiting the planet. Whenever the next supernova does go "bang," a battalion of sophisticated instruments will slew rapidly to cover it. Twenty years ago we'd have been limited to ground-based views through a murky, distorting atmosphere.

In putting together this excellent work on supernovae, the Murdins have gathered a great deal of information that ranges from studies of oriental oracle bones from the dawn of history to recent issues of *The Astrophysical Journal*. Given that supernovae are a specialized topic in astronomy, an author might be tempted to lay heavily into the details of the models and number-crunching, assuming an already-initiated reader. To their great credit the Murdins have restrained themselves, and therefore the book is accessible and interesting to all but the most uninformed reader.

They begin with a survey that draws on Chinese, Japanese, and Arabic records. In all, we know of six "historical" supernovae: in 185 A.D., 386, 393, 1006, 1054, and 1181. These were followed by the two "Renaissance" supernovae in 1572 and 1604. For the last two we have excellent positions and careful comparison magnitudes made by professional astronomers. (The magnitudes are good enough, in fact, to determine that both of these supernovae were of Type I, the more common of the two types of outburst.

History then leads the authors to a detailed account of the Crab Nebula, the remnant left after the supernova of 1054. Nearby and fresh, the Crab Nebula is one of the most intensively-studied objects in the sky. Although the Crab supernova may have been the rarer Type II outburst, and although the structure of the Crab (filled with gaseous material) is different from that of most other remnants (having a shell structure), the authors use the Crab as a means of introducing much of the basic astrophysics needed for understanding supernovae.

The Crab and its mysteries lead naturally to pulsars, the rapidly spinning neutron stars which are all that is left after a star goes supernova. From pulsars we progress to a closer look at the gassy remnants — the stars' outer shells, thrown off at speeds of 15,000 kilometers a second or more — and how they interact with the interstellar medium.

The next few chapters focus on the processes that lead up to a star exploding as a supernova and the various pathways of stellar evolution that can bring even undersized stars to the point of detonation. And finally, the authors examine the role that supernova explosions play in the creation of elements and their effects on star-formation in a galaxy.

Supernovae is an excellent and readable book. I recommend it highly to anyone with more than the most casual interest in astronomy. You'll enjoy it and will come away with a clear understanding of Mother Nature's most gigantic event. *Robert Burnham.*

Strategic Defense:
Star Wars in Perspective
Keith B. Payne
250 pages, paper, $9.95
Hamilton Press (1986)

Payne's book is an examination of the Strategic Defense Initiative proposed by President Reagan in March 1983. This controversial defense program is appraised as the only real deterrent mankind has in the shadow of the failure of present offense-oriented deterrence policies. The social and political implications of SDI are also considered.

Relativistic Astrophysics
Marek Demianski
341 pages, cloth, $45
Pergamon Press (1985)

This text, designed for research students of astronomy, covers the physics of accretion disks, gravitational radiation from binary pulsars, gravitational lenses, the role of grand unified theories of elementary particles in cosmology, and theories of galaxy formation. It also covers advances in pulsars, galactic x-ray sources, electromagnetic gravitational wave detectors, and the density wave theory of spiral galaxy arms.

From Sputnik to Space Shuttles
Franklyn M. Branley
53 pages, cloth, $11.95
T. Y. Crowell (1986)

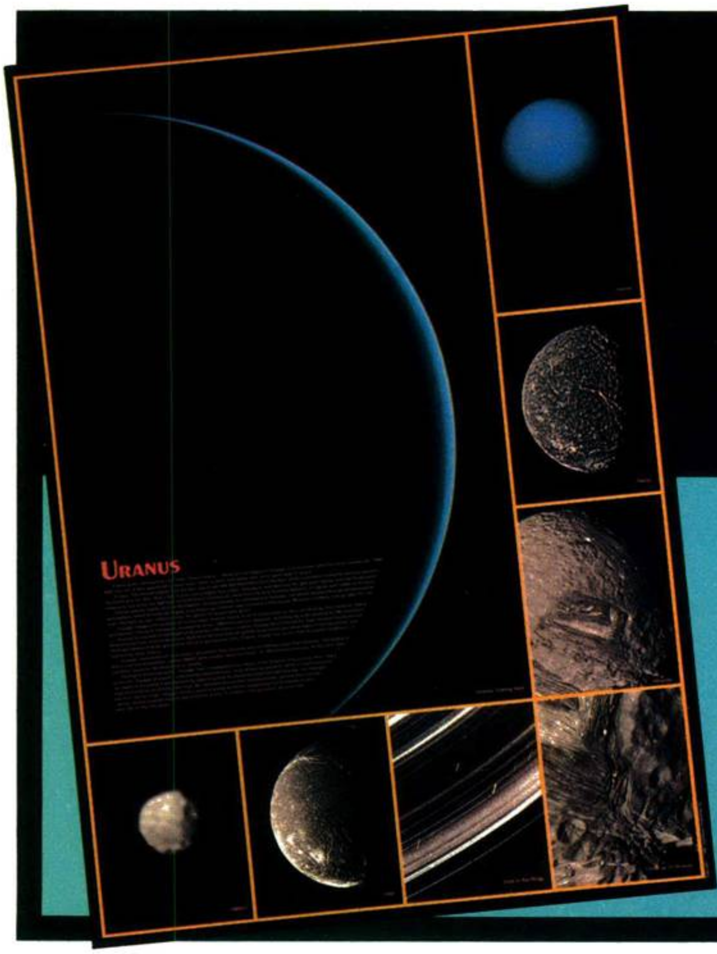
This is a young person's guide to satellites and space science as well as possible future space stations.

History of Cosmic Ray Studies
Yataro Sekido and Harry Eliot, eds.
444 pages, hardcover, no price given
D. Reidel (1985)

This book is a collection of personal reminiscences by many of the scientists directly involved in the development of cosmic ray research. Over one hundred photographs and thirty-six written accounts are presented here covering the period since 1912, when Victor Hess discovered cosmic rays during a balloon flight. Included are articles by three Nobel Prize Laureates: Hannes Alfven, Carl Anderson, and Hideki Yukawa.

Astronomy with
Your Personal Computer
Peter Duffett-Smith
256 pages, paper, no price given
Cambridge University Press (1985)

The set of twenty-six subroutines collected here covers a wide range of calculations of potential interest to amateur astronomers. Written in BASIC, the programs are not specific to any make of machine. They are intended to be used as a set of linked subroutines that can be combined into complex programs to meet a reader's own requirements.



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Sky With Ocean Joined

Steven J. Dick and Leroy E. Doggett, eds.
190 pages, paper, $10
U.S. Naval Observatory (1983)

These are the proceedings of the sesquicentennial symposia of the U.S. Naval Observatory held in December 1980. The first part of the book covers the history of the Observatory, and the second part deals with the Observatory's current and future scientific programs, many of which will contribute to basic astronomical research.

Astrophysics of Active Galaxies and Quasi-Stellar Objects

Joseph C. Miller, ed.
519 pages, cloth, $30
University Science Books (1985)

This book contains the proceedings from the 7th Santa Cruz Workshop on Astrophysics, held at the University of California at Santa Cruz in July 1984. Included among the papers are: "Low-Luminosity Active Galactic Nuclei" by William C. Keel; "Observations of Broad Emission-Line Regions" by Donald C. Osterbrock; and "The Galaxies Associated with Quasi-Stellar Objects and Active Nuclei" by Joseph C. Miller.

Dynamics of Comets: Their Origin and Evolution

Andrea Carusi and Giovanni B. Valsecchi, eds.
439 pages, hardcover, $59.50
D. Reidel (1985)

This volume contains the proceedings from Colloquium 83 of the International Astronomical Union held in Rome, Italy, in 1984. The colloquium was divided into several sessions that covered the origin of comets, the Oort cloud, meteor streams and interrelations with minor planets, the dynamics of comets, nongravitational forces, Comet Halley, and future spacecraft missions to comets.

The Cosmic Inquirers

Wallace and Karen Tucker
221 pages, cloth, $20
Harvard University Press (1986)

Approaching the concerns of modern astronomy from the astronomers' perspective, *The Cosmic Inquirers* discusses today's ground- and space-based telescopes and the struggles of their designers to make them a reality. Each chapter is based on interviews with a number of pioneers in the fields of optical, gamma ray, infrared, and high energy astronomy.

Almanac for Computers 1986

Nautical Almanac Office
74 pages, paper, $3.50
U.S. Naval Observatory (1985)

This publication provides astronomical data in mathematical expressions and IAU constants for computers and calculators. The expressions allow direct calculation of astronomical and navigational data for specific times and conditions.

Barnes & Noble Thesaurus of Science and Technology

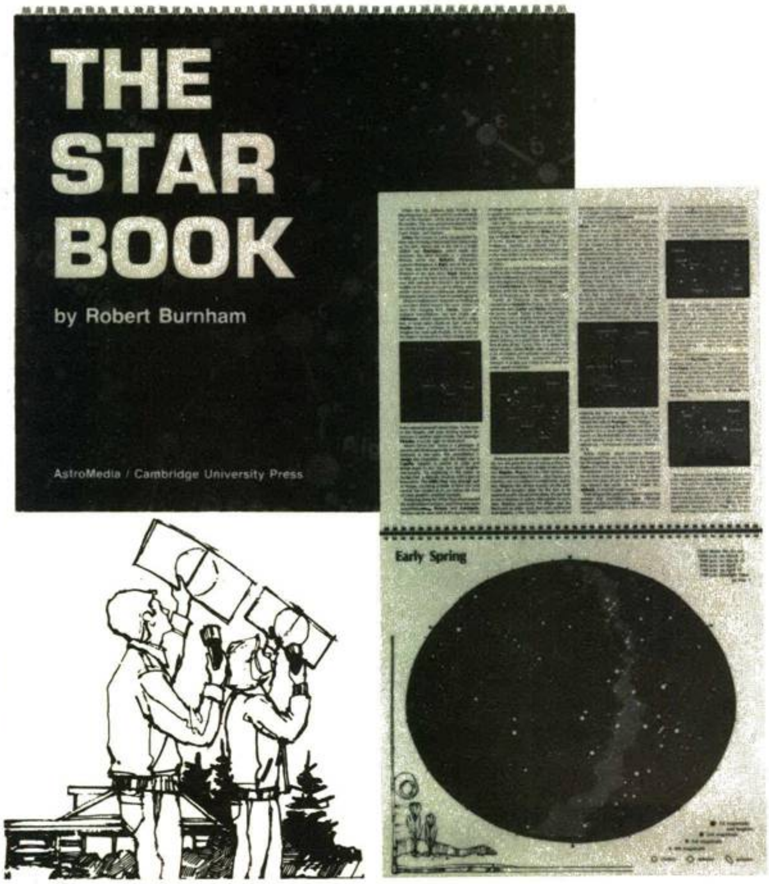
Arthur Godman and Ronald Denney
256 pages, paper, $8.95
Barnes & Noble (1986)

Barnes & Noble's thesaurus lists some 2,000 scientific words in astronomy and other fields and provides definitions along with colored line drawings explaining the meanings of scientific terms and phrases.

Dark Companions of Stars

Peter van de Kamp
327 pages, cloth, $44.50
D. Reidel (1986)

In this book's foreword Dutch astronomer Peter van de Kamp begins with a



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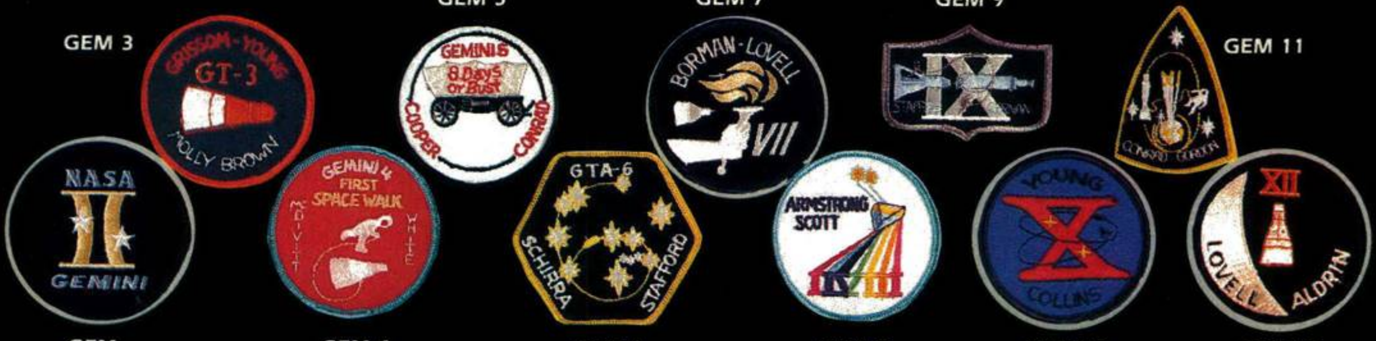
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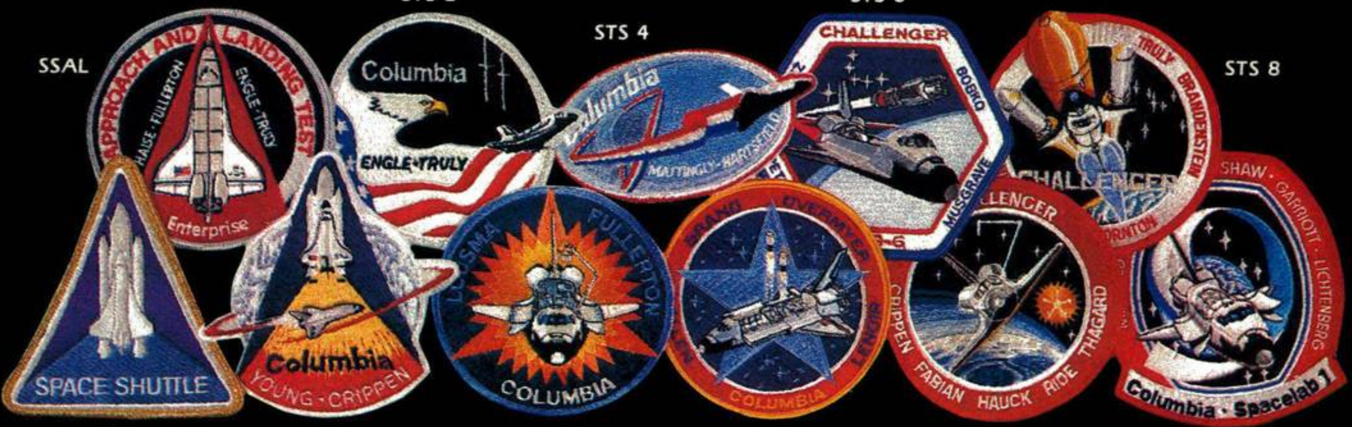
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quotation from *The Talmud*: "If you want to understand the invisible, look careful at the visible." With this in mind, van de Kamp details many years of research on hidden companions to stars using astrometric techniques.

Methods in the Qualitative Theory of Dynamical Systems in Astrophysics and Gas Dynamics
Oleg I. Bogoyavlensky
301 pages, cloth, $49
Springer-Verlag (1985)

This book is an analysis of multidimensional dynamical systems with applications to cosmological problems, theoretical astrophysics, and gas dynamics.

The Electronic Sky:
Digital Images of the Cosmos
Photographs by Rudolph Schild and Thomas Stephenson, text by Rudolph Schild and James Cornell
41 slides, 20-page booklet, no price given
Smithsonian Institution (1985)

CCD images taken at the Whipple Observatory on Mt. Hopkins in Arizona were sent to the Harvard-Smithsonian Image Processing Laboratory, where these slides were made. Among the techniques shown are color enhancement, topographic imaging, contour imaging, use of false color, color contours, brightness profiles, and degraded resolution.

The Cosmic Onion
Frank Close
182 pages, cloth, $25
The American Institute of Physics (1986)

The Cosmic Onion is a popular-level book about particle physics that concentrates on quarks. Chapter titles include "The Forces of Nature," "The Weinberg-Salam Model of the Weak Force," and "Quantum Chromodynamics."

Astronomy and Astronautics:
An Enthusiast's Guide to Books and Periodicals
Andy Lusis
292 pages, cloth, $24.95
Facts On File (1986)

This reference book lists 968 books and periodicals about astronomy, astronautics, and related subjects, providing one-paragraph summaries of their contents.

Black Holes: The Membrane Paradigm
Kip S. Thorne, Richard H. Price, and Douglas A. MacDonald, eds.
367 pages, cloth, $40
Yale University Press (1986)

Black Holes is a mathematical volume on black hole theory for professionals and students of cosmology. The book's preface explains that presenting black holes as a "membrane paradigm" means that they should be accessible to anyone with a thorough grounding in relativistic astrophysics, rather than only to experts in black hole theory.

Wave Propagation and Scattering
B.J. Uscinski, ed.
381 pages, cloth, $59
Oxford University Press (1986)

Wave Propagation is a technical proceedings volume that contains papers presented at the symposium on Wave Propagation and Scattering in Random Media, held at Cambridge University in April 1984. Included are such topics as "Radio Wave Scattering in the Interplanetary and Interstellar Media," "Quasi-Periodic Scintillation Patterns," and "Microwave Backscatter from the Sea Surface."

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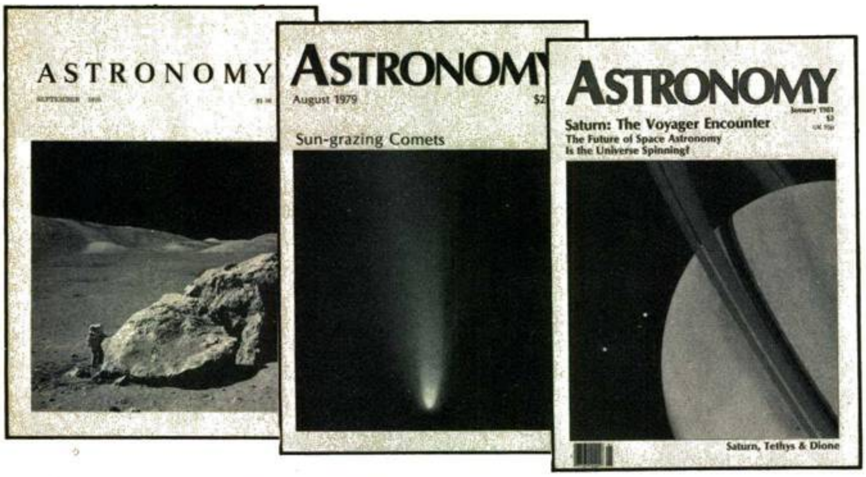
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Gazer's Gazette

Learning the Sky by Degrees

by Jim Loudon

The appearance of the sky to the casual observer is very different from the actual structure of the universe. Like ancient astronomers, we only perceive the two-dimensional aspects of celestial objects, though our knowledge better explains the phenomena we see. We now know that the Sun and Moon appear to merge during a solar eclipse because one object is far behind the other in the sky's imperceptible third dimension — depth. Likewise two stars that seem close together in the sky are almost always nowhere near each other in space (unless they are physical double stars or cluster members).

But we can't "see" the three-dimensional structure of the heavens. Instead, the night sky looks like a huge hemispherical bowl arching over our heads. The stars appear fixed on its inner surface and, as far as we can tell without using sophisticated instruments, never vary their positions with respect to one another from season to season.

This imaginary sphere, centered on the observer and bisected by the horizon, is called the celestial sphere. Although we know that the celestial sphere is only an artifice and that stars and galaxies extend into nearly limitless space, we still utilize this primitive concept to help us find our way among the stars.

Units of Angular Measurement

We frequently wish to indicate a particular star or other celestial body to another person. Simply pointing at the star is often infuriatingly inexact.

Given that the stars Dubhe and Merak in the Big Dipper point to Polaris, just how far away from Dubhe is Polaris? If you think the question is trivial, try explaining the answer to a fifth-grader sometime. A child usually thinks Polaris should be right next to the Dipper. When he realizes it isn't, he ends up looking halfway around the sky for it. (In fact, one of the biggest problems beginners have in learning constellations is that the figures in the sky look so much bigger than their diagrams in star charts.) So how can we measure something as big as the Big Dipper or the entire sky?

The answer is to use degrees. The simplest way of specifying the position of a star in the sky is to give its "angular distance" from something whose location is already known, like another star or the horizon.

"Distance" refers to the distance along the imaginary surface of the celestial sphere — angular distance — not some actual distance between the stars. The fact that Polaris is separated from Dubhe in the sky means we must look in a different direction to see Polaris. Draw an imaginary line from your eye to Polaris; then draw another from your eye to Dubhe. These "lines of sight" form an angle that is a measure of how far Polaris is from Dubhe on the celestial sphere.

The fact that lines of sight are also radii of the celestial sphere (since the observer is at the sphere's center) means that an arc drawn along the sphere from Dubhe to Polaris is equal, in degrees, to the angle between the two lines of sight. The arc and angle are interchangeable measurements; either one serves as the definition of the angular distance between (or angular separation of) the two stars. In the case of Dubhe and Polaris, the measurement is 29°.

Before we continue, you should commit to memory the following values:

- A circle is divided into 360°.
- A half circle, such as the hemisphere of the night sky, is 180°.
- From horizon to overhead (a right angle) is 90°.
- Each degree is divided into 60 minutes of arc (60′).
- Each minute of arc is divided into 60 seconds of arc (60″).
- 1° = 60′ = 3600″.
- 360° = 21,600′ = 1,296,000″.

Apparent Size

In addition to objects that are naked-eye point sources (stars and most planets) and have position only, the sky contains "extended" sources, like the Sun and Moon, which have apparent size as well as position. An extended source takes up a measureable portion of the sky, instead of being a dimensionless point. The fact that an object is extended means we must look along two lines of sight to see both edges of the object. We define the angle between these two lines of sight as the angle the object subtends. Its size is the angular separation of the two edges. The Moon, for example, subtends half a degree, or 30′.

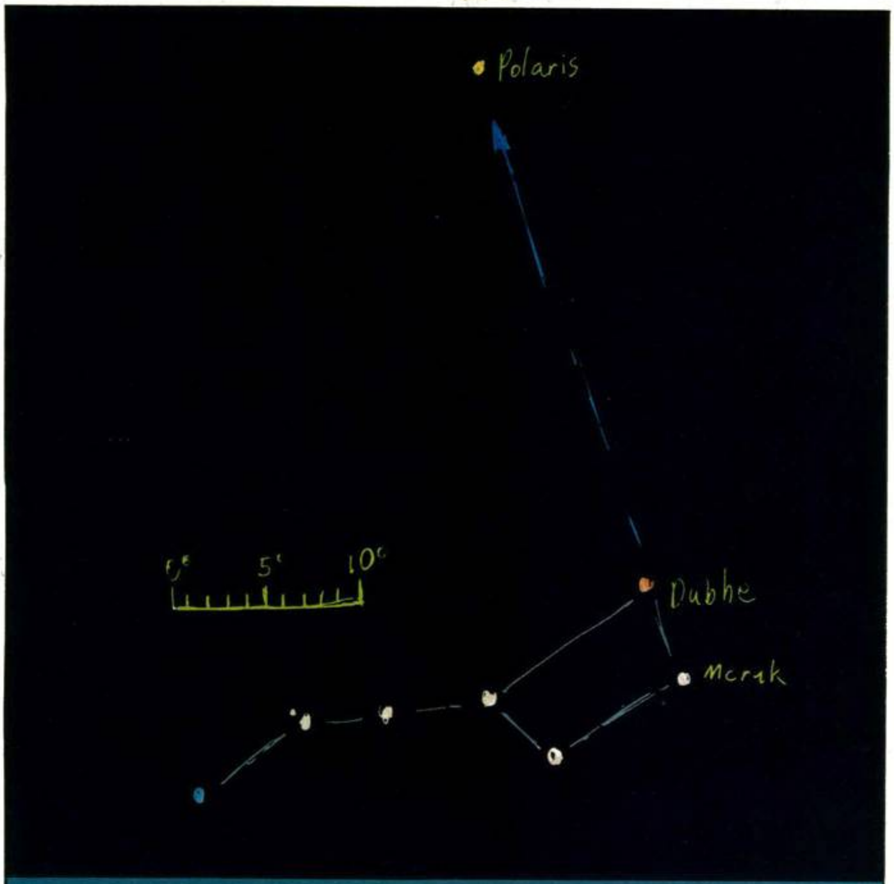
If an extended source does not appear circular, it will subtend a different angle in different directions. The Lagoon Nebula in Sagittarius is roughly rectangular and measures 90′ by 40′ (though the full extent of the nebula cannot be seen in small telescopes).

A subtended angle, then, is a measure of the apparent size of an object, that is, how big it looks in the sky and how much of the field of view it covers, as opposed to its true diameter. If a building blocks your view of the sky from the horizon halfway to the zenith, it subtends a 45° angle from your location. An aspirin tablet held at arm's length subtends the same half-degree angle as the Moon. By an interesting coincidence the Sun, as seen from Earth, also subtends half a degree, which is why the Moon almost exactly covers the Sun during a total eclipse. Even though the Sun's diameter is 400 times that of the Moon, the Sun is also 400 times as far away as the Moon, and therefore looks the same size in our sky.

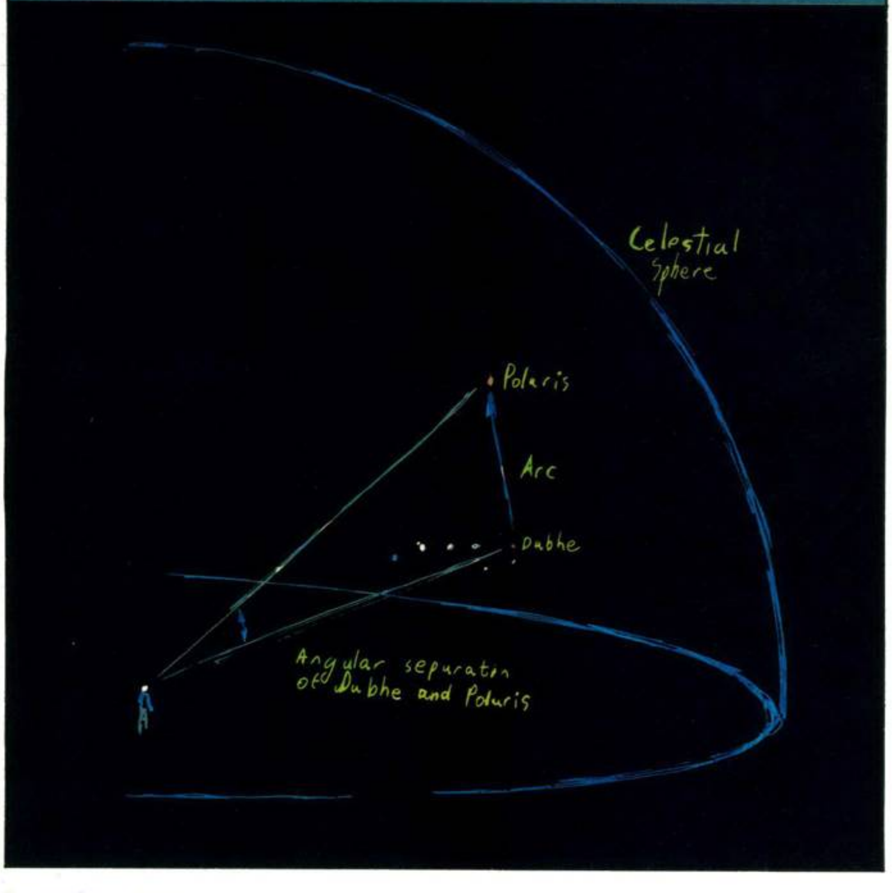
You can measure angular distances and subtended angles with your fist held at arm's length. Coincidentally, it subtends an angle that is approximately 10°. (People with smaller fists also have shorter arms.) To measure larger angles, simply place one fist on the other, and so on. Be careful not to move the stationary fist as you place the other one on top of it. From the horizon to directly overhead should be nine fists (90°). If it doesn't work, try it again; you're probably moving the fist that should be stationary.

The Distance-Diameter Link

The relationship between the apparent



Above: As seen from Earth, Polaris lies 29° from Dubhe.
Below: If we imagine that the stars are fixed to the celestial sphere, we can consider the lines of sight to two objects as forming an angle. Because the lines of sight are radii of the sphere, the arc drawn between Dubhe and Polaris is equal to the angle.



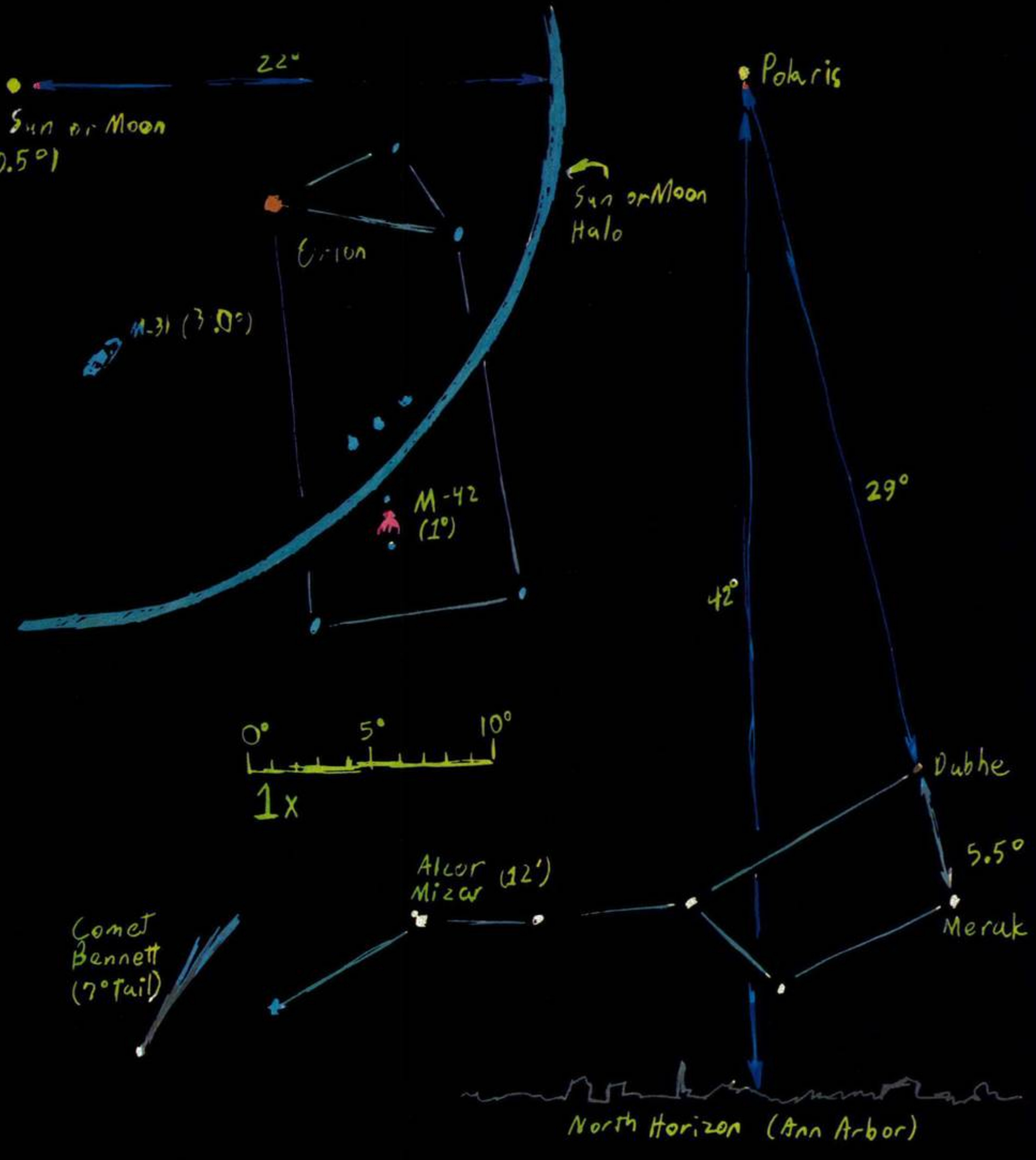
A Child's Garden of Subtended Angles

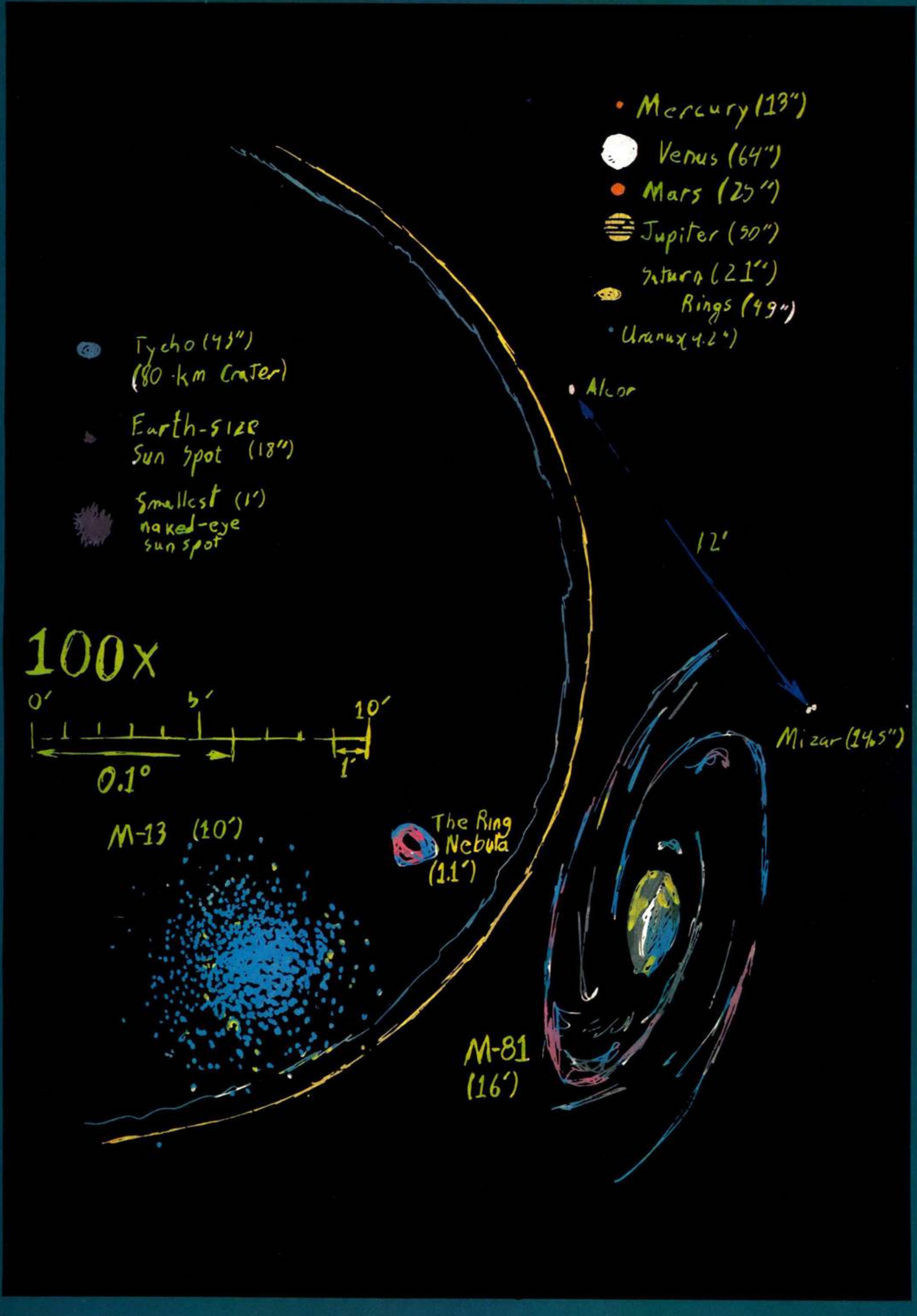
To get anywhere in astronomy you have to know all the angles. The drawings on the next two pages are meant to give you some feeling for the apparent sizes of typical astronomical objects. The illustrations are drawn to the scale indicated on each page. The objects on page 56 are shown at actual size and the objects on page 57 are shown 100 times larger. For accurate representation of angular size, hold each page 10 inches from your eyes.

All objects are shown as seen from Earth unless otherwise stated. Apparent sizes of some of the bodies shown vary as their distances change. The Sun and Moon are shown at their average sizes. Planets are shown at their greatest possible sizes. Three of them vary substantially: Mars from 25″ to only 3.5″ (less than Uranus); Venus, from 64″ to 10″; and Mercury, from 13″ to 5″. Finally, objects with vaguely defined boundaries (nebulae and galaxies) are shown as they appear in normally exposed telescopic photographs. Such objects are often brightest at the center and fade smoothly away from it.

Comparing the objects to one another may lead to some surprises. For example, few nonastronomers appreciate that a medium-size lunar crater looks bigger through a telescope than the entire body of any planet. That's why planetary photographs taken from Earth invariably look fuzzy: it's necessary to magnify them enormously to discern detail. Galaxy photographs do not usually look fuzzy because, as the drawings illustrate, there are many galaxies that are far bigger in the sky than the planets, despite the galaxies' far greater distances. M-31, in fact, subtends five times the angular diameter of the Moon.

Great distance need not imply small apparent size. One of the biggest physical objects in the sky (as opposed to, say, constellations, which are merely accidental patterns of unrelated stars and not real objects at all) is more distant than anything shown in the drawings: the Virgo Cluster of galaxies occupies no less than 12°of the sky even though it is 15 megaparsecs away.


22°
Sun or Moon
(0.5°)
Sun or Moon
Halo
Orion
M-31 (3.0°)
M-42
(1°)
Polaris
29°
42°
0°
5°
10°
1x
Dubhe
5.5°
Alcor (12')
Mizar
Merak
Comet
Bennett
(7° Tail)
North Horizon (Ann Arbor)


Mercury (13")
Venus (64")
Mars (25")
Jupiter (50")
Saturn (21")
Rings (49")
Uranus (4.2")
Tycho (43")
(80-km Crater)
Earth-size
Sun Spot (18")
Smallest (1')
naked-eye
sun spot
Alcor
12'
Mizar (14.5")
100x
0'
5'
10'
0.1°
1'
M-13 (10')
The Ring
Nebula
(1.1')
M-81
(16')

angular size of a celestial object and its actual size and distance is described by the object's distance-diameter ratio. The apparent angle subtended by an object — in the sky or on Earth — is determined by the ratio of its true diameter to its distance. Any object with a distance that is 110 times its diameter will subtend half a degree. The Moon has a diameter of 3,476 kilometers and its average distance is 384,622 kilometers, roughly 110 times its diameter. An aspirin at arm's length subtends a half-degree like the Moon, and its distance is also 110 times its diameter.

Similar statements can be made for other distance-diameter ratios. Any object whose distance exactly equals its diameter subtends an angle slightly under 60°, which is called one radian. Any object whose distance is twice its diameter subtends half a radian (about 30°). Any object whose distance is three times its diameter subtends one third of a radian, and so on. In general, an object whose distance is N times its diameter subtends 1/N radian.

The preceding paragraph is true, however, only if (1) all parts of the object lie at the same distance from the observer, in other words, along an arc, and (2) the diameter is measured along this arc. If the angle subtended is small (as is usual in astronomical cases), the value is usually very close to being correct. Even when the angle is as large as 60°, it errs by less than 10 percent. However, for much bigger angles (when the distance is *smaller* than the diameter), the relationship deteriorates rapidly. For rough calculations you can assume that one radian equals 60°. However, for precise work, the true value of the radian is $360°/2\pi = 57.3°$.

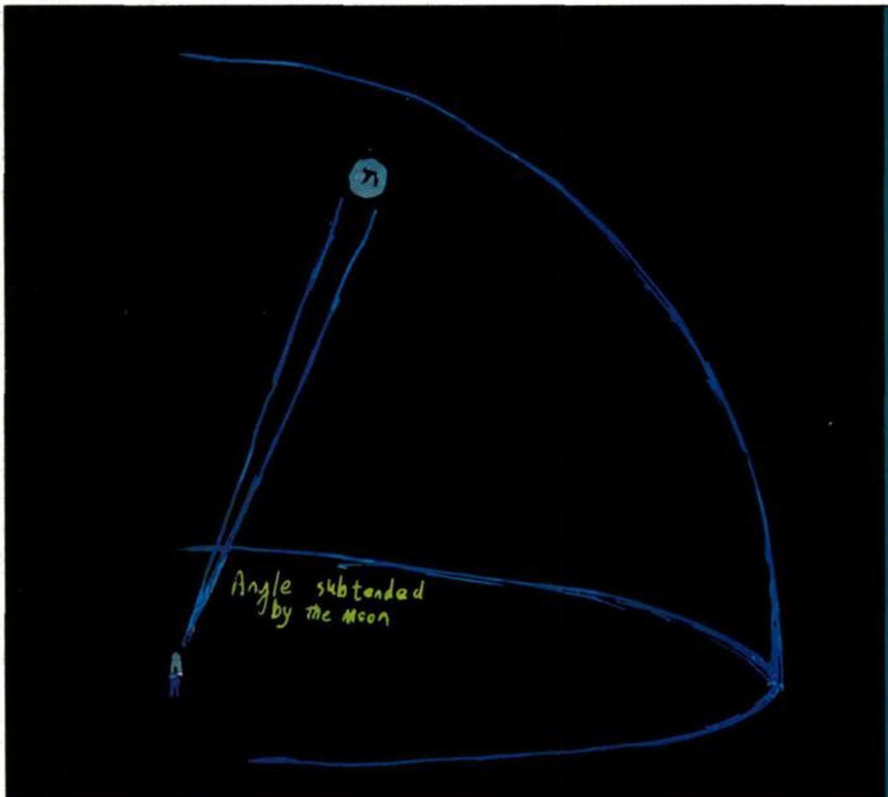
Let's try an example. Ann Arbor, Michigan, is about 8 kilometers across. How big would it look to an astronaut passing directly over the city at a distance of 400 kilometers? Could he see Ann Arbor with the naked eye?

Rather than do the arithmetic exactly, we'll make an approximation. The distance (400 kilometers) is 50 times the diameter (8 kilometers). Therefore the city's apparent size is 1/50 times 60°, or a bit over 1°. This is twice the apparent diameter of the Moon. Clearly there would be no trouble seeing the city as far as size is concerned. (However, visibility also requires contrast; if Ann Arbor does not stand out from the surrounding country, it would be hard to see.)

Limits of Perception

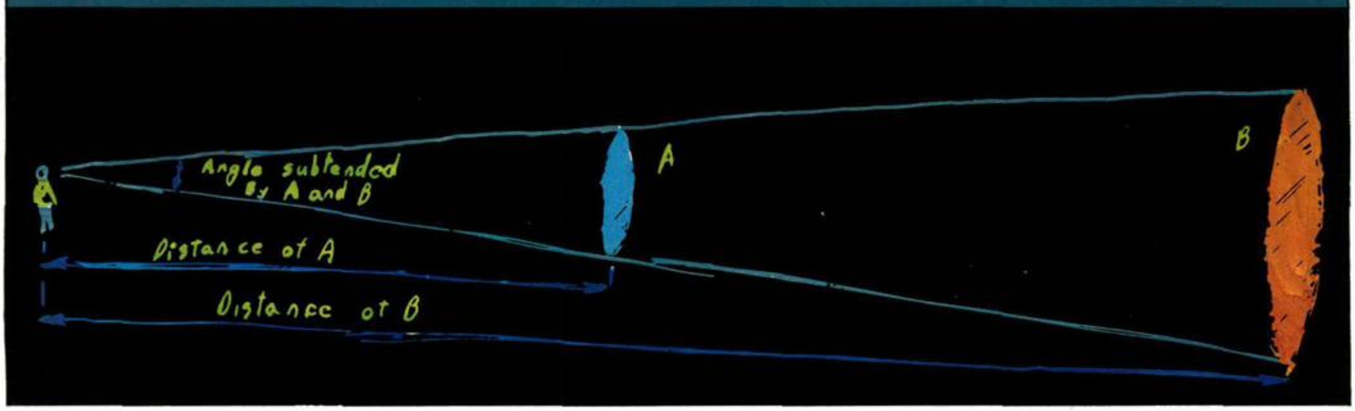
So far, we've concerned ourselves with measuring apparently bulky things like the Moon, the Sun, and Ann Arbor, Michigan. But what about the realm of the apparently very small? How do we deal with something like a star, which appears to have no size to speak of?

There is really no such thing as a true point source, that is, a light source that has zero size. In actual use, "point source" refers to a source that subtends such a small angle that you can't measure it using



Left: Because an extended object is larger than a point source, we have to look in different directions to see each side. Lines of sight "drawn" to both sides of the object from an observer subtend an angle that represents the angular diameter of the object. In this illustration, one edge of the Full Moon is slightly *more than half a degree from* its opposite edge. (The angle here is exaggerated).

Below: Any two objects with identical distance-diameter ratios subtend the same angle. Objects A and B subtend the same angle because A exactly blocks the view of B.



the instruments you have.

Which sources you consider to be "points" will depend on your instruments. For example, the naked eye has no trouble seeing the Moon as a disk rather than a point. However, most people cannot see the crescent phase of Venus when it is closest to Earth, even though it subtends about 64″. No one sees Jupiter (50″) as anything but a point.

On the other hand, even a small telescope shows Jupiter as a disk. The same telescope may have trouble with Neptune, which is 2″ across. No telescope will show Pluto as a disk, and its diameter is uncertain for that reason. The stars are all points to any Earthbound telescope, since atmospheric turbulence makes any source smaller than 1″ look like a 1″ disk.

The star of largest known apparent size is the variable star Mira (Omicron Ceti), which subtends only 0.056″, the same size as a dime in Detroit observed from Ann Arbor, 64 kilometers away. A 200-inch telescope in space (where it would be unaffected by the Earth's atmosphere) could show the disks of Mira and a few other giant and supergiant stars like Antares and Betelgeuse, but most stars would still be seen only as points.

Under ideal conditions, the human eye can resolve (see as an extended object) anything subtending more than a 1′ angle. Objects smaller than that are seen as point sources if they are bright objects on a dark background. Theoretically, then, a double star separated by 1′ or more can be "split" (seen as two stars rather than a single point of light) by the naked eye, provided the two components are of nearly equal brightness. Nevertheless, it is not easy for most observers to split Epsilon Lyrae with the naked eye even though its primary components are 3.1′ apart.

An object subtends 1′ if its distance is 3,438 times its diameter. Examples are a quarter seen across the length of a football field; the football field seen from 320 kilometers above Earth; or Earth seen from a distance of 44 million kilometers. The best Earthbound telescopes are usually limited by atmospheric effects to objects 1″ or larger in apparent size, though in moments of good "seeing" resolutions of 0.25″ are occasionally realized. (Of course, this refers to their apparent size in the sky before they are magnified by the telescope. For the eye to see a 1″ object, the telescope must magnify it until it looks 1′ across or bigger.) The distance-diameter ratio for 1″ is 206,265.

Thus, telescopes can show detail only 1/60 as small as the unaided eye can see. In theory, then, you could see everything your telescope can show you with a magnification of only 60x. In practice, higher magnification is usually needed. As mentioned earlier, the naked eye achieves 1′ resolution only under ideal circumstances. Could *you* see a quarter at the other end of a football field?

"Ideal conditions" for visibility include maximum contrast, such as a black object on a white background. On a clear day with snow on the ground, Lake St. Clair, a roughly circular body of dark, polluted water near Detroit, should fulfill this condition. Its diameter is about 38.6 kilometers. Could you see it from the Moon? The distance-diameter ratio is 384,622 km/38.6 km = 9,964.3. Since the smallest object the naked eye can see is one at a distance of 3,438 times its diameter, the answer is no. You could see any of the Great Lakes, however — clouds permitting.

What is the angular separation of the Earth and Moon as seen from Venus at its nearest (40,232,500 kilometers)? Could the unaided eye see them as a double "star" or would they look like a single dot? (Assume you could see the sky through the clouds!)

The term diameter here is the Earth-Moon distance: 384,622 kilometers. The separation is then:

384,622/40,232,500 × 60° = 0.57°
which is slightly larger than the apparent size of the Moon seen from Earth. Clearly there would be no trouble splitting the two when the Earth and Moon were farthest apart and Venus was at its closest approach. The Moon would appear as a yellow "star" about as bright as Jupiter seen from Earth. The Earth would be a brilliant blue "star" 80 times brighter, considerably more brilliant than any point source in our sky.

Perceiving the Apparent Sky

Psychological phenomena relating to the apparent sky deserve brief mention because you can get very confused if you don't realize they exist.

Depending on where they are in the sky, celestial objects may appear considerably bigger or smaller than they are. When a constellation is just rising, it looks bigger than it will later, when it is near the zenith. This effect is also seen on the sizes of the Sun and Moon. Everyone knows how big the Full Moon looks as it rises above the treetops. Yet 720 Full Moons placed edge to edge would be required to once around the horizon; 11 Full Moons could fit between the pointer stars of the Big Dipper.

Psychologists call this effect the "Moon illusion." You can easily prove that it is only an illusion by photographing the Moon when it is near the horizon and again when it is near the zenith, and then comparing the image sizes.

The origin of the Moon illusion is only partially understood. Apparently we perceive the sky not as half a sphere but as half an oblate spheroid — in other words, the sky overhead seems closer to the observer than the horizon. A celestial object that is perceived as "projected" onto this distorted sky bowl seems bigger at the horizon because we see that it still subtends the same angle though we perceive it as being farther away. The horizon, stretching away from us, also gives us a sense of greater distance. When the object is near the zenith, where there are no terrestrial reference points to imply distance, the object looks smaller.

Another illusion, size constancy, may shed some light on the Moon illusion. Hold your hand about 8 inches from your face. Now move it 2 feet away. How much smaller does it look? The correct answer (it appears one-third as big) is hard to believe. Our minds do not perceive the more distant hand as smaller, but as the same size, only farther away.

Size constancy illustrates the sophisticated way our minds process sensory data. In visual situations where there is no physical contact with the object, the only information we have is angular size or angular separation. But the data we need to determine the object's true size are its linear dimensions and distance. Through a long learning process that began as soon as you were born, your mind has acquired the ability to interpret angular visual data in terms of linear dimensions.

In most cases, you do this so well that you never realize you're doing it. A child and a man subtending equal angles in different parts of your visual field don't confuse you for an instant. You correctly interpret the information you have about each in terms of what you know about their heights and distances. You probably would not even notice that their apparent sizes were equal unless your attention was specifically called to the fact.

But you have never formed a solid feeling for the linear sizes of celestial objects by touching and manipulating them as you have for most everyday objects. Therefore it is not surprising that your mental data-processing mechanisms may give false results when they attempt to cope with sensory input from the sky.

Unlike ancient astronomers, we recognize the truths behind the illusions. We know that the apparent size of a celestial object is indeed a factor of its inherent size as well as its true distance. The Sun has the apparent diameter it does because of its true size and distance from Earth. If the Sun were intrinsically larger or closer, its apparent disk would be larger too. This same relationship holds for planets, stars, and galaxies.

Taken together, the apparent and true values *do* reflect on spatial distances and structures in the universe. When you consider that the Virgo Cluster extends across 12° of sky and is still 15 megaparsecs distant, you get a profound idea of the true size of the cluster and, by inference, of the structure of galaxy clusters in general.

The sky is the only perspective we have of the real universe. Although we don't have to go beyond appearances to learn about aspects of the apparent sky, understanding the apparent sky is an essential part of exploring and understanding the universe.

Jim Loudon is a lecturer, teacher, and writer on astronomy and space. He is currently staff astronomer at the University of Michigan Exhibit Museum.

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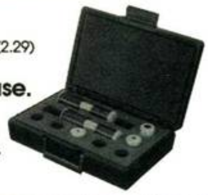

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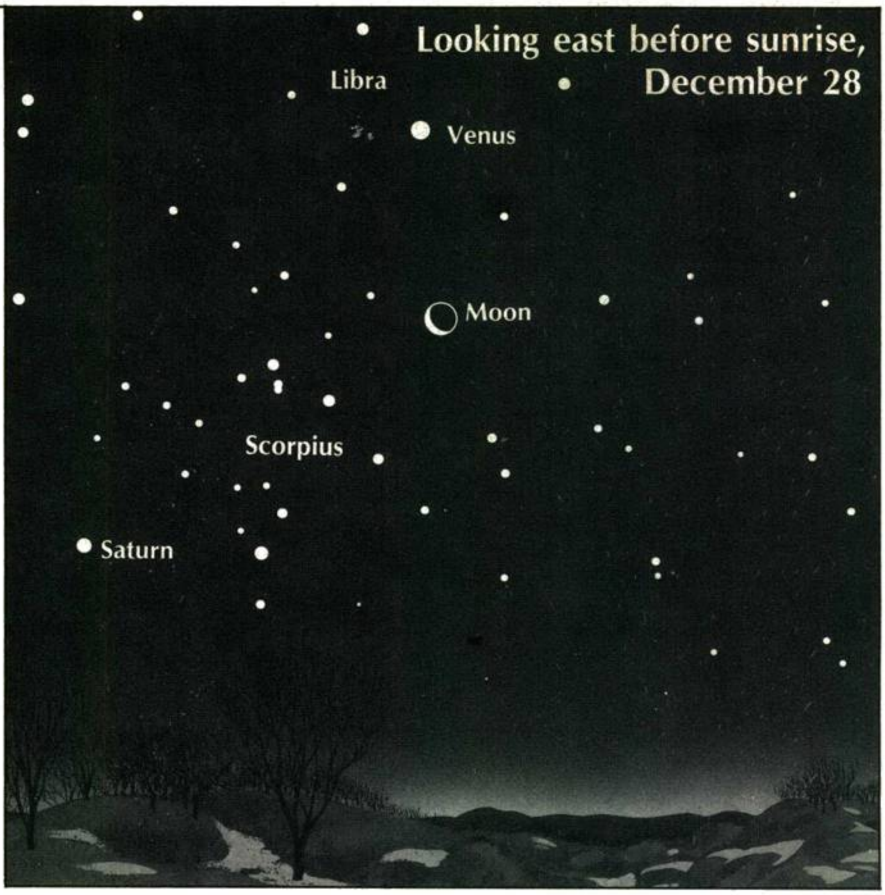
Eye on the Sky

Mars Meets Jupiter

by Robert Burnham


Looking east before sunrise, December 28

The Wanderers

Since June 21, the Sun has daily traced an ever-lower path across the sky and the hours of daylight have steadily shortened. On December 21 (at 11:02 p.m. EST) the Sun at last "touches bottom" and immediately begins its northward trek again. At this instant, called the **solstice** ("Sun-stand"), the Earth's north pole tips farthest away from the Sun. It marks the beginning of winter in the Northern Hemisphere.

Nightfall reveals two planets together in the evening sky. Stand outside where you have a clear view to the south. A little east of due south and about halfway up in the sky lie two conspicuous "stars." The brighter is **Jupiter**; gleaming white, it shines at magnitude −2.4. To its right, dimmer and honey-amber in color, is 0.3-magnitude **Mars**. Both are in the constellation Aquarius.

Mars moves more quickly than Jupiter because it orbits closer to the Sun. As the evenings pass you'll see Mars creep toward Jupiter. Finally, on the 19th, the two will lie just 31′ (about one Moon-diameter) apart, with Mars due north of Jupiter. As the year closes, Mars will draw eastward away from Jupiter. Try a nightly series of tripod-steadied photos (centered on Jupiter) using a medium telephoto lens and exposures of 0.5, 1, 2, and 5 seconds.

After Mars and Jupiter set around midnight, no other planets rise until shortly before dawn. Get up an hour before sunrise, dress warmly, and go where you have a good view to the southeast.

Covered in white clouds, **Venus** appears blazingly bright. It recently passed between the Sun and Earth and is now prominent in the southeastern sky before sunrise. At magnitude −4.6, it is brighter than anything except the Sun and Moon. Venus shines so brightly that, in a dark sky, it casts a faint shadow. To see for yourself, find some fresh snow or other white surface that's illuminated only by Venus. (Do it early in the month before the Moon interferes.) Then peer closely at the surface while you move your hand back and forth several inches away. See the shadow? If not, let your eyes dark-adapt for a few minutes and try again. Be sure there's no light spilling onto the surface from street or porch lights.

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

Mercury is also in the predawn sky and is seen best only during the first days of December. On December 1, find a viewing site with an unobstructed eastern horizon and look for it to the lower left of Venus and at about half its elevation. Amber-colored Mercury shines at magnitude −0.6. Each morning it will lie a little lower and by the 22nd or so will be too close to the Sun to be seen at all.

As Mercury sinks, **Saturn** climbs into view. By the third week of December Saturn will be visible low in the southeast an hour before sunrise. Saturn has a brightness of magnitude 0.4 (about the same as Mars) and is cream-white in color. From low beginnings Saturn rises slightly higher each day.

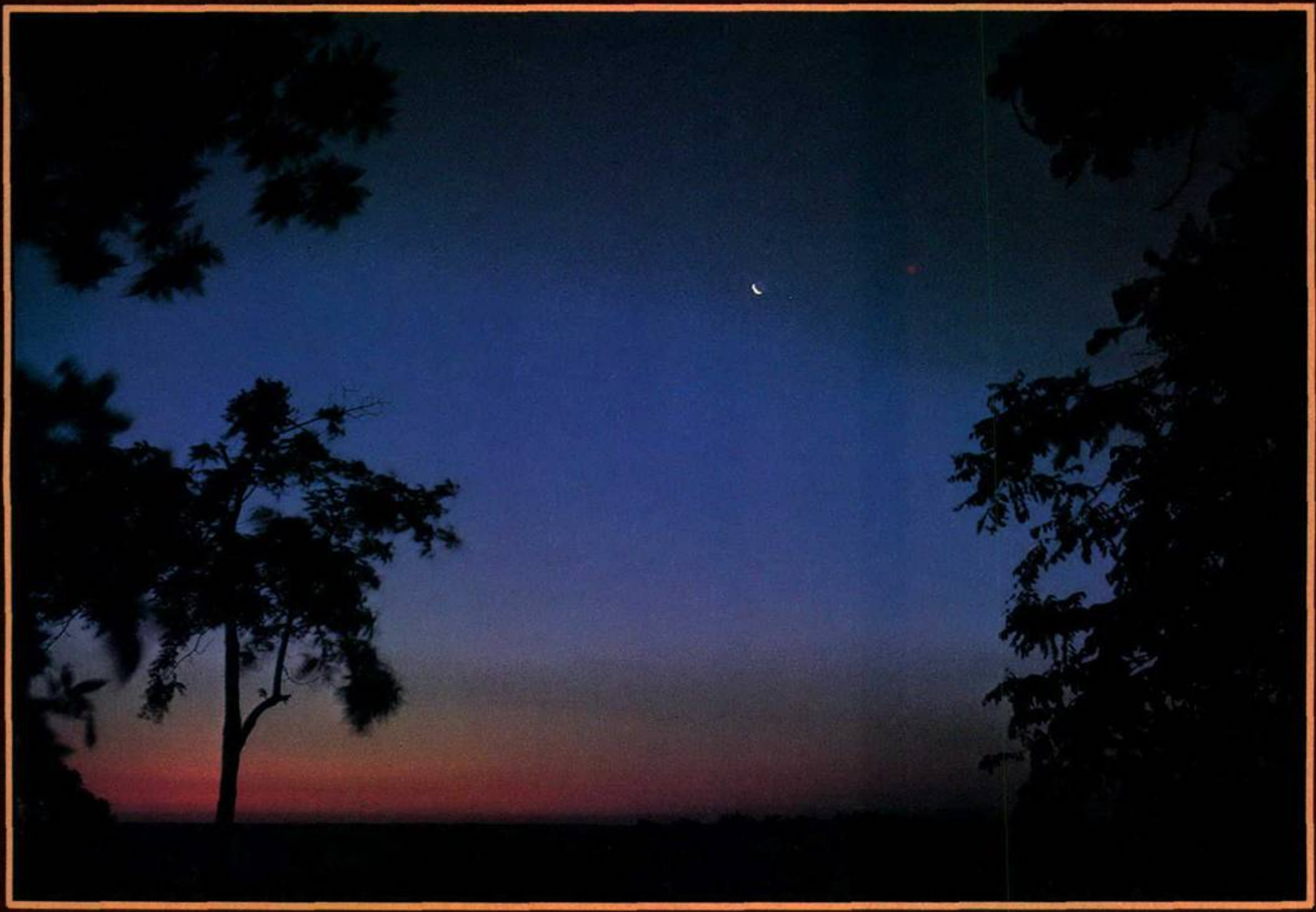
December has two **meteor showers**: the **Geminids**, which peak in the predawn hours of the 14th, and the **Ursids**, which peak on the 22nd. Unfortunately, the Moon is a problem for both showers. On the 22nd the Last Quarter Moon will be rising in the east around midnight. From a dark site you could see about sixty Geminids an hour coming from near the star Castor, but the Moon will obscure many of them this year. The Ursids (from Kochab in Ursa Minor) are a sparse shower, and the nearly full Moon will reduce the show to ten meteors an hour.

Top right: Small hexagonal ice crystals can act like thousands of tiny mirrors producing a parahelia or "sundog." This sundog was photographed by Stephen Parker using a 200mm telephoto lens and Kodachrome ISO 25 film.

Bottom right: Mark Jones captured this tranquil scene of the crescent Moon and Venus in the morning sky, June 1985, using a 35mm lens at f/3.6, Kodachrome 64 film, and a 3-second exposure.

The Starry Sky

Climbing the eastern sky in mid-evening is a constellation many people recognize: **Orion** the Hunter. The star Rigel marks one knee with red Betelgeuse marking his opposite shoulder. North of Betelgeuse a few dim stars indicate his upraised club. From Bellatrix — Gamma (γ) — more dim stars depict a shield on his other arm. Opposite Rigel is Saiph — Kappa (κ) — the Hunter's eastern knee.

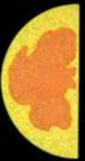


December Night Sky

New Moon
December 1
11:43 a.m. EST

First Quarter
December 8
3:01 a.m. EST

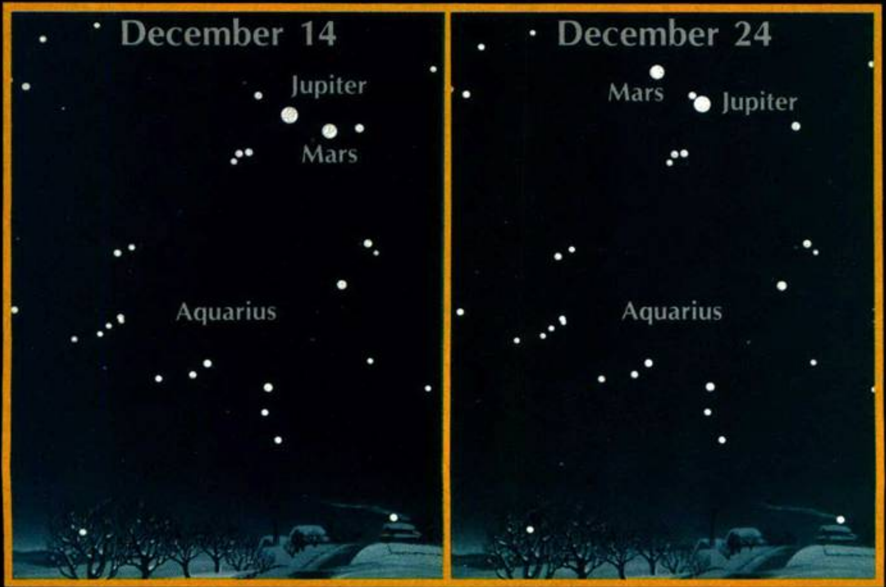
Full Moon
December 16
2:04 a.m. EST

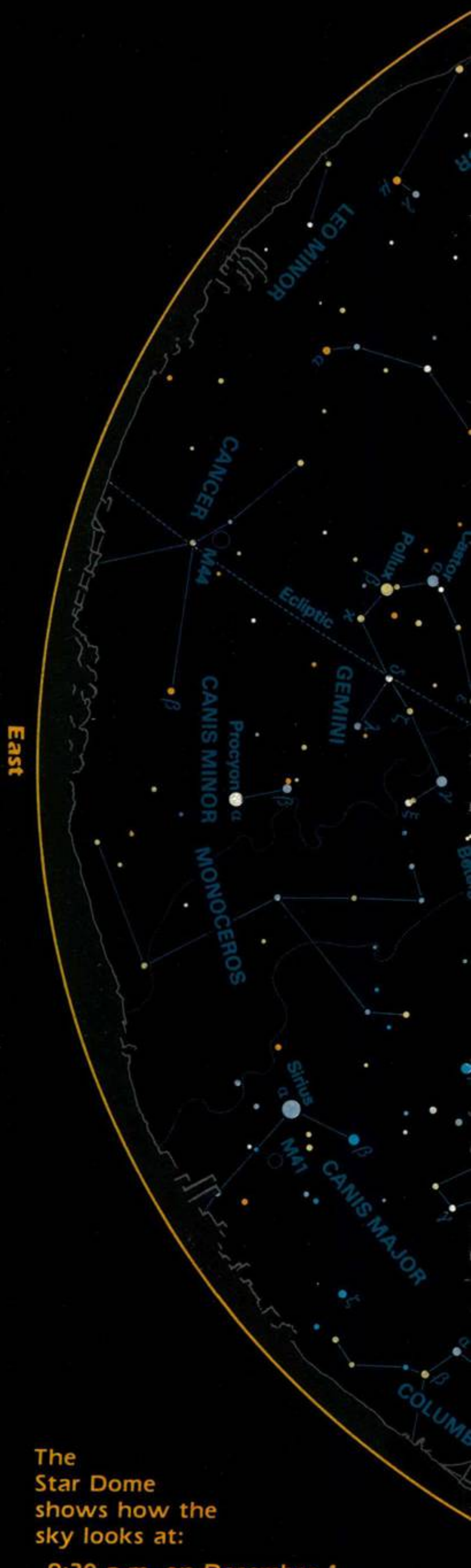

Last Quarter
December 24
4:17 a.m. EST

New Moon
December 30
10:10 p.m. EST

1st	New Moon occurs at 11:43 a.m. EST.
2nd	The Moon is close to Earth (the first of two perigees this month) at 5:32 a.m. EST: 222,287 miles (357,726 kilometers).
4th	Saturn is in conjunction with the Sun; it will reappear low in the southeastern morning sky after the 15th.
8th	First Quarter Moon is at 3:01 a.m. EST.
11th	Venus is at greatest brilliancy (magnitude −4.6) in the morning sky.
14th	The Geminid meteors are at their best during the predawn hours. Uranus is in conjunction with the Sun.
16th	The Moon is Full at 2:04 a.m. EST.
17th	The Moon is farthest from Earth at 12:06 a.m. EST: 252,592 miles (406,496 kilometers).
19th	Mars passes half a degree north of Jupiter, 1:46 a.m. EST.
21st	The solstice occurs at 11:02 p.m. EST, marking the start of winter.
22nd	The predawn hours today are the best time to view the Ursid meteor shower.
24th	Last Quarter Moon occurs at 4:17 a.m. EST.
27th	Neptune is in conjunction with the Sun.
30th	The Moon is close to Earth for the second time this month at 6:15 p.m. EST: 221,590 miles (356,604 kilometers). New Moon occurs at 10:10 p.m. EST.

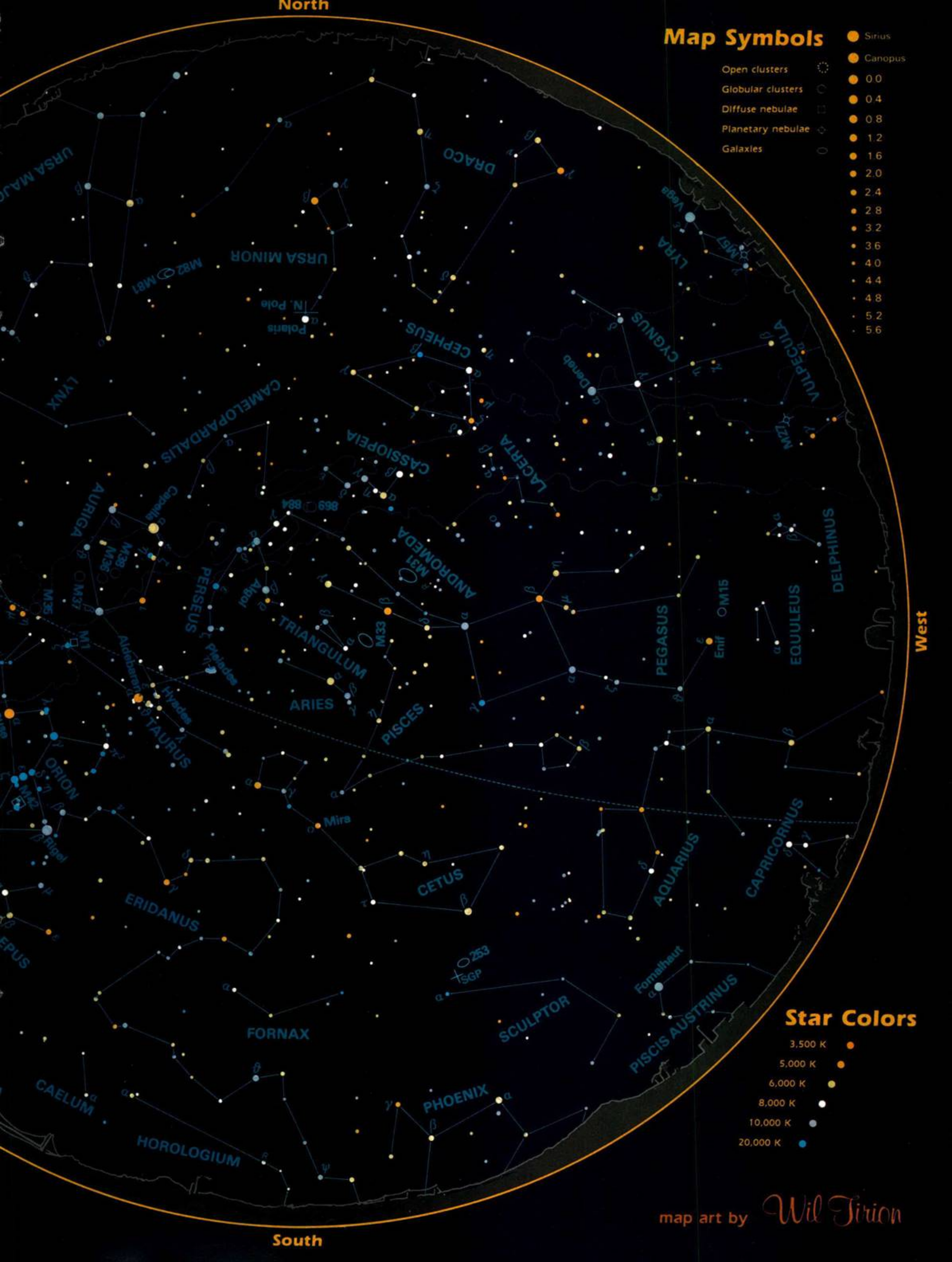
Looking south after sunset


December 14
Jupiter
Mars
Aquarius
December 24
Mars
Jupiter
Aquarius

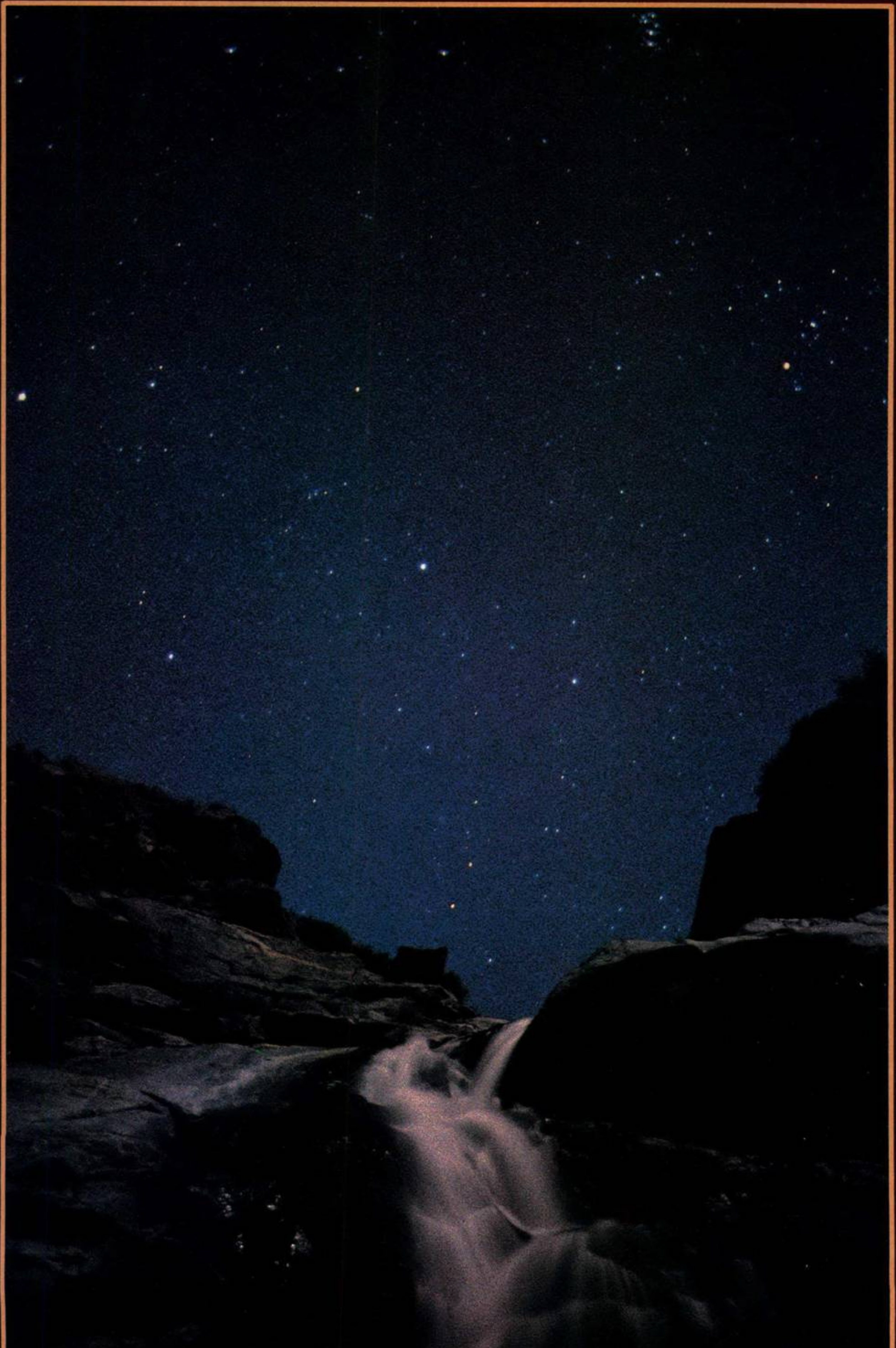

East
LEO MINOR
CANCER
M44
Pollux
Castor
Ecliptic
GEMINI
Procyon
CANIS MINOR
MONOCEROS
Sirius
M41
CANIS MAJOR
COLUMB

The Star Dome shows how the sky looks at:

9:30 p.m. on December 1
8:30 p.m. on December 15
7:30 p.m. on December 31


North
South
West
Map Symbols
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies
Sirius
Canopus
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
4.4
4.8
5.2
5.6
Star Colors
3,500 K
5,000 K
6,000 K
8,000 K
10,000 K
20,000 K
URSA MAJOR
DRACO
URSA MINOR
M81
M82
N. Pole
Polaris
LYRA
Vega
M57
CYGNUS
Deneb
VULPECULA
M27
CEPHEUS
LYNX
CAMELOPARDALIS
CASSIOPEIA
LACERTA
AURIGA
Capella
M38
M36
M37
M35
869
884
PERSEUS
Algol
ANDROMEDA
M31
M33
TRIANGULUM
PEGASUS
M15
Enif
EQUULEUS
DELPHINUS
M1
Aldebaran
Pleiades
Hyades
TAURUS
ARIES
PISCES
ORION
M42
Rigel
Mira
CETUS
ERIDANUS
AQUARIUS
CAPRICORNUS
EPUS
253
SGP
FORNAX
SCULPTOR
Fomalhaut
PISCIS AUSTRINUS
CAELUM
PHOENIX
HOROLOGIUM

map art by Wil Tirion



Opposite page: Auriga, the Pleiades, and Taurus provide the backdrop for this waterfall in the Cleveland National Forest, California. The scene was illuminated by the First Quarter Moon. Photo by Jerry Schad, who used a 35mm lens at f/2 and 3M 1000 film.

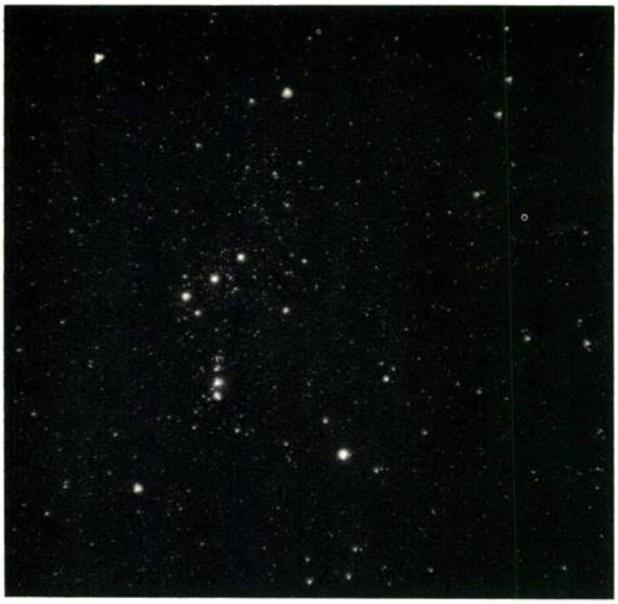
Three stars in a vertical line cross Orion's middle to form his belt; from bottom up they are Alnitak, Alnilam, and Mintaka. If you have a small telescope you should be able to see Mintaka's bluish companion just north of primary.

About halfway between Alnitak and Rigel look for the several faint stars of the Hunter's Sword. These contain M-42, the Great Orion Nebula, which appears as a small dim glow in a pair of binoculars. A telescope reveals the nebula as a beautiful glowing cloud of gas extending south from the quadruple star Theta (θ), also known as the Trapezium. These stars formed out of the nebula about 100,000 years ago. Because they are young and very hot, they are heating the nebula so that it glows. Many other stars are also forming deep within the cloud.

Orion's opponent is **Taurus** the Bull. Warm-hued Aldebaran marks the Bull's angry eye. Far behind this star spreads the loosely-gathered members of the Hyades star cluster. The other bright star cluster in Taurus is the lovely Pleiades. The so-called Seven Sisters embody a small mystery since most people can detect only six stars with the naked eye. Yet some keen-eyed observers claim to have seen many more, up to eleven in one authenticated case. Pick a clear, dark night when the stars hardly twinkle and see how many you can count — but no cheating with binoculars!

From the Hyades, Taurus' horns extend downward and to the left. One horn points to the Twins, **Gemini**, found also by extending a line from Rigel through Betelgeuse. Gemini is the constellation from which this month's Geminid meteor shower appears. Taurus' other horn jabs **Auriga** the Charioteer, a pentagon of stars containing the yellow 1st-magnitude star Capella. The Charioteer rolls along the **Milky Way**, though to see its gentle glow you'll have to get away from the city.

Above Auriga lies **Perseus** the Rescuer or, as many call him, the Hero. Perseus is formed from two branches of 3rd-magnitude stars and isn't prominent. The constellation commemorates the hero who saved **Andromeda** from being eaten by the sea-monster Cetus. The maiden Andromeda herself adjoins Perseus on the west and consists of two diverging lines of stars that spring away from one corner of Pegasus' Great Square. Can you see a patch of haze where the map indicates M-31? This is the Great Galaxy in Andromeda, a near-twin to the Milky Way but 2.5 million light-years away.



The constellation Orion is a distinctive grouping rising just after sunset. Below the three "belt" stars in the "sword" is the Orion Nebula, M-42, where many stars are forming from collapsing clouds of gas. M-42 is a striking object in binoculars and small telescopes. Photo by Robert Gewin.

Perseus' mount, **Pegasus** the Flying Horse, is a large figure in the western part of the sky. His body and wings are formed by the Great Square while his neck and head point downward (as you face west); Enif marks his nose.

Adjoining Andromeda is her mother **Cassiopeia** the Queen. If you look north, Cassiopeia resembles a splay-footed "M". Now look between Cassiopeia and Perseus where the map shows 869 and 884. This is the famous Double Cluster, one of several "nebulous" spots in the heavens known to the ancients. Today we know them to be two star clusters at about the same distance from us. They make a fine sight in binoculars and small telescopes.

Andromeda's father was **Cepheus**, King of Ethiopia. His constellation lies generally below Cassiopeia when you face north and looks like an elongated pentagon. Cepheus' feet stand in the Milky Way and his head lies close to Polaris, the pole star, which belongs to **Ursa Minor** the Lesser Bear. Continuing down the Milky Way to the northwest we pass **Lacerta** the Lizard, a dim zig-zag of 4th-magnitude stars.

The last figure to identify tonight is **Cygnus** the Swan. Poised on its beak and ready to set, Cygnus towers above the western horizon. Cygnus is a summer constellation that lingers late, disappearing only when winter begins.

Skylore

If Greek mythology teaches us any lesson, it's that the gods were a nasty, evil-tempered bunch. In legend after legend mortals were either punished with ingenious ferocity for ordinary human failings or killed outright, usually through a clumsy mistake by one of the gods. Poor Orion suffered both.

As the story goes, Orion was the son of Poseidon, ruler of the sea. Born in Boeotia (which meant "Hicksville"), Orion was strong, very handsome, and a great hunter. He also had the ability (thanks to his father) of walking on or through the ocean, no matter how deep.

One day he came to the island of Chios in the eastern Aegean. It was ruled by King Oenopion, who had a lovely daughter named Merope. Orion fell in love with Merope and asked Oenopion for permission to marry her. The king, incestuously in love with Merope, refused Orion but set him the task of ridding the island of its dangerous wild beasts, after which, he said, he would allow the marriage.

Orion set out at dawn every day, returning long after dusk laden with skins and pelts. Finally he was finished. But when he claimed Merope, Oenopion demurred and mentioned rumors he'd heard about wild creatures that hadn't yet been caught.

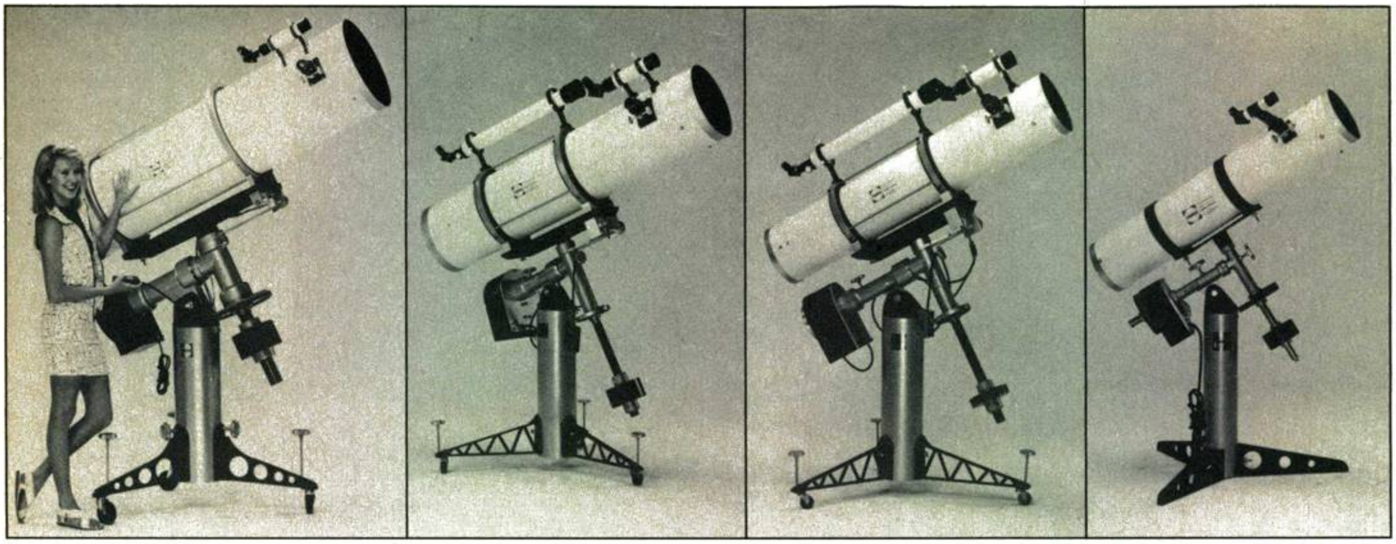
By now Orion had figured out the real situation. But childishly upset, he got drunk one night and took Merope by force. The next day the king, legitimately angered but secretly glad of the pretext, got Orion falling-down drunk again and had his eyes put out. Then, while Orion was still unconscious, the king dumped him on the seashore.

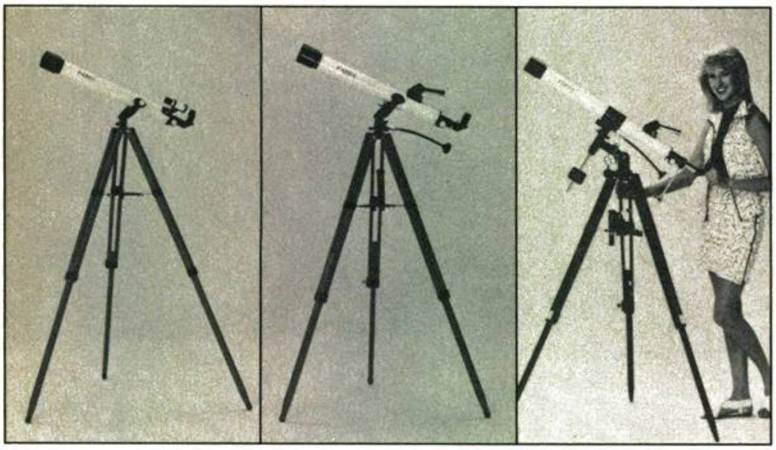
A prophecy told that Orion could have his sight back if he journeyed to the east and faced the Sun when it first rose. Orion found a boat and, drawn by the clang of hammers, traveled to the smithy of Hephaestus on the island of Lemnos. Borrowing one of the workers as his guide, Orion eventually reached the eastern edge of the world. There the goddess of morning, Eos, fell in love with him while the brilliant rays of light from her brother Helios, the Sun, restored Orion's vision.

Eos was a pleasant companion but, after spending some time with her, Orion wanted to return to Chios and get revenge on Oenopion. When he reached the island, the king was in hiding and so escaped Orion's wrath. Meanwhile, Orion met Artemis, the Moon-goddess and patroness of the hunt.

We'll see what followed this fateful encounter next month.

PARKS . . .





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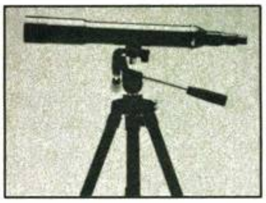

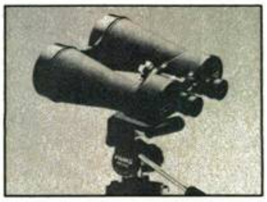

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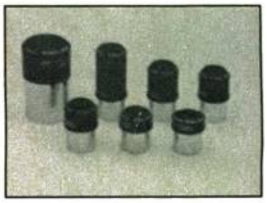

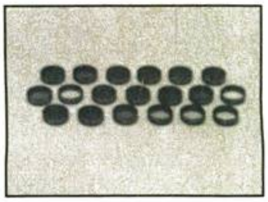

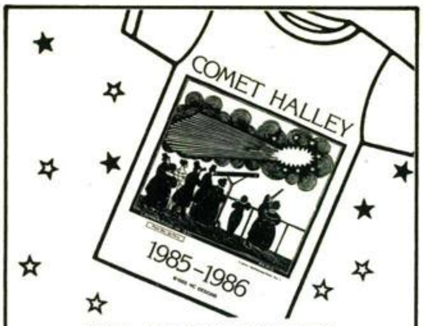

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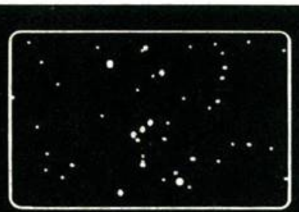

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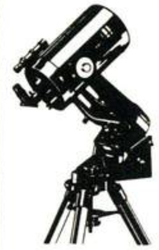

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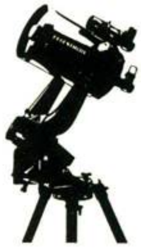

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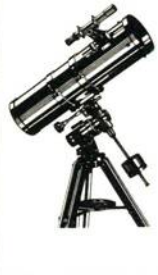

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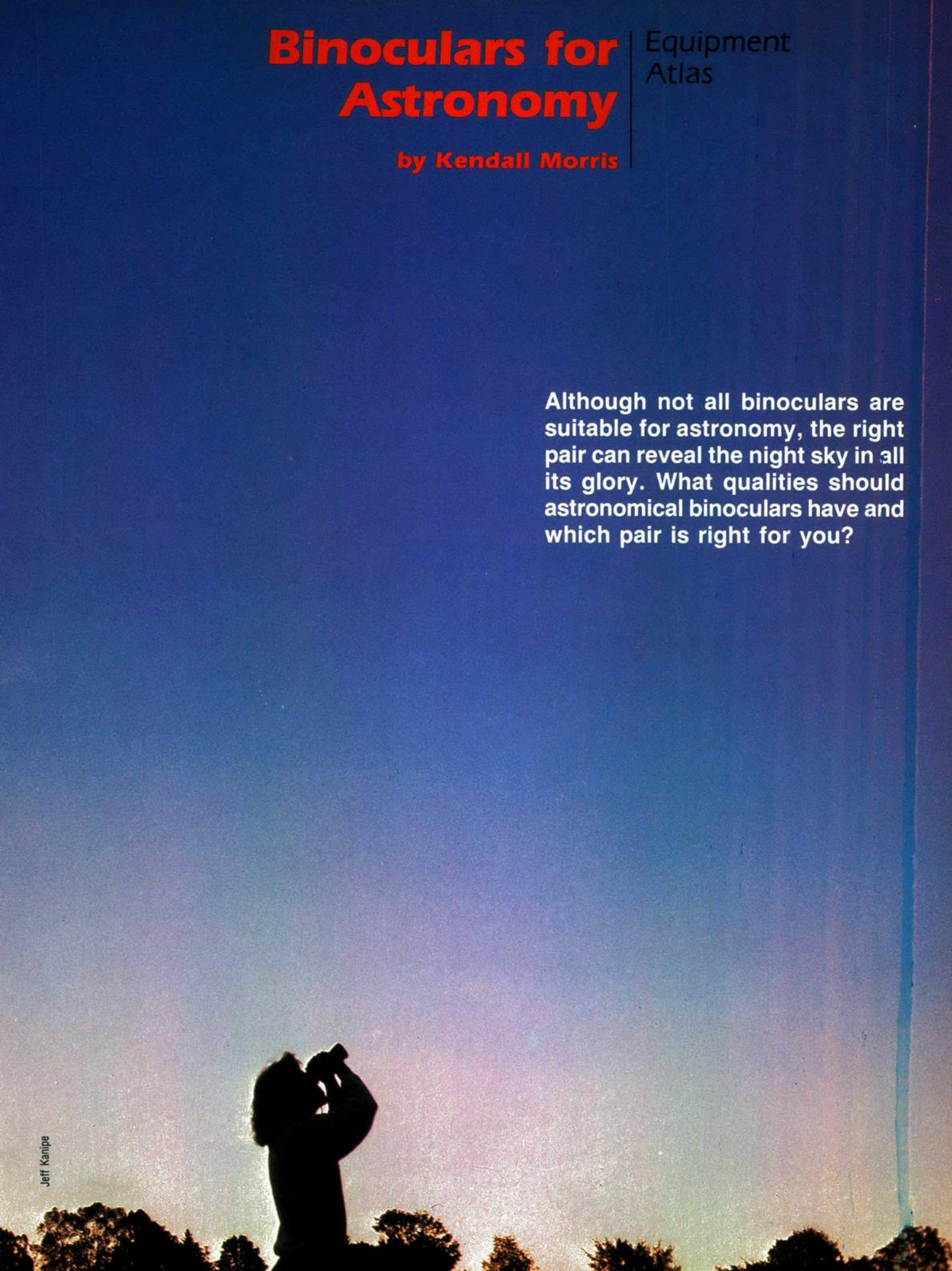
Binoculars for Astronomy

Equipment Atlas

by Kendall Morris

Although not all binoculars are suitable for astronomy, the right pair can reveal the night sky in all its glory. What qualities should astronomical binoculars have and which pair is right for you?



Jeff Kanipe

In the last few years, binoculars have become the instrument of choice for many amateur astronomers. Portability, affordability, and the depth and dimension of sky that can be seen with both eyes are the reasons often cited for the growing popularity of binoculars. During Comet Halley's apparition many observers discovered that binoculars rendered the best overall views of the comet, especially during its post-perihelion passage when its tail length exceeded 8°. And for wide-field views of the Milky Way, the Andromeda Galaxy, and the crescent Moon, binoculars are unparalleled.

Their increasing popularity in astronomy has stimulated the manufacture of new models better-suited for looking at stars, planets, and deep-sky objects. Unfortunately this proliferation has not made the buyer's job any easier. With such a wide variety of types, sizes, and costs to choose from, it's hard to decide what's best. What distinguishes a superior-quality binocular from a mediocre one? How can you assess the optical design and function of a particular pair of binoculars? How can you tell which model is best for you?

It's easiest to begin by asking which types are *not* suitable for astronomy. There are a number of them. At the bottom of the pile are what are sometimes advertised as "50 mile non-prismatic binoculars," which cost about $10 (or sale priced at two for $15!). These are not true binoculars but cheap two-lens optical systems. Because of their similarity to Galileo's telescope, this lens arrangement is referred to as a Galilean system. They usually have a plastic objective lens and a plastic concave (negative) eyepiece. Apart from their optical (awful) and mechanical (terrible) performance, this design gives a very narrow field of view. Looking through them is like looking through a drinking straw.

Just a little better are opera glasses. These have low-powered, two-lens Galilean optical systems. They also suffer from a narrow field of view, typically less than 20°.

Also in the Galilean family are a great number of "field glasses." These normally magnify about four times and range in quality from useless to adequate. Even the best, however, suffer from a narrow field and weak optics.

Good binoculars should have optics that render bright, clear, high-contrast images. Ideally, focusing should be true across the entire field and the images free of "color fringing" caused by the inability of the optics to bring various wavelengths of light to focus at the same point. Peering through the eyepieces should not be like looking through two tubes but like looking out a window with a generous field of view.

Alignment of the optics is another important factor, because your eyes will try to compensate for imprecise alignment of the barrels and prisms. Even a slight error in alignment will result in eye strain and, if the binoculars are used for very long, a headache.

Not surprisingly, good binoculars are also more expensive than those of lesser quality. Fine optics and craftsmanship take more time and effort. But even among the highest quality models there are design factors and optical specifications that may limit or conflict with your long-term observing purposes. So if you decide to purchase an expensive pair of binoculars, you still have a number of particulars to consider before laying your money down.

Mechanical Considerations

Binoculars come in two major body types: the two-piece body German or Z style and the one-piece body American or B style. In the Z style the separate front barrels that hold the objective lenses are screwed into the body. This type of construction unfortunately allows the optics to be easily knocked out of alignment. Dust and moisture are also more apt to get inside the body because the separate cover plates near the objective barrels and the eyepieces don't always form a perfect seal.

The B style is usually sturdier and better sealed. In addition the optics in the higher-grade B styles are better collimated because the prisms can be firmly seated and aligned on separate plates before they are inserted into the body. The prism plates of the Z-style units, however, are part of the body, so the prisms must be installed and seated inside. Most Z styles (and some inexpensive B styles) are also optically aligned to the center hinge by moving the individual prisms. This can degrade the image somewhat if the prisms tilt too far out of alignment with the eyepieces.

Another mechanical factor to consider is focusing. Two types of focusing are used: individual eyepiece focusing and center focusing. Center focusing comes in wheel and lever styles. The wheel style utilizes a knurled cylinder located on the hinge line which, when rotated, moves the eyepieces to focus. The lever style works in the same manner, except that the wheel is replaced with a lever, platform, or semi-cylinder that "see-saws" to move the elements in and out of focus. This type of focus is much faster than the wheel because its basic mechanism is a cam device instead of a threaded screw system. It is also more precise and allows the binoculars to be focused faster than a person's eye can adapt. Images snap into sharpness without eye strain. With a slower focusing system the user's eye does some of the focusing work and so is under constant muscular strain.

Sadly, however, lever focus systems are often made with sloppy and loose mechanisms. Because of the many poorly made lever focusers presently available, these systems have the reputation of being inferior.

The individual eyepiece system requires that each eyepiece be slowly turned to focus. This system is slow, requires the eye to adapt to the system unless focusing is done with care (by focusing, moving the binoculars out of your field of view, looking briefly through the binoculars, and re-focusing), and is unsuitable for use by several people when they each focus differently. But it is sturdy and easy to seal. In fact, most waterproof and military binoculars are of individual focusing design.

Coating: A Test for Quality

Undoubtedly one of the most critical factors in determining the quality of binoculars is whether or not the optics have been coated. No matter what the aperture and magnification, binoculars will not render bright, crisp images if the lenses are not coated.

A plain glass surface that is not coated reflects about 4 percent of the light from both the outside and inside surfaces (inside the body). However, a surface that has been properly coated reflects about 1.5 percent.

The coating is deposited onto the glass by evaporation while it and the glass are in a vacuum chamber, similar to the way mirrors are coated with aluminum. The coating most commonly used, the metallic salt magnesium fluoride, has the opposite effect of aluminum. Magnesium fluoride increases the transmission of light passing into the glass instead of reflecting the light away from the surface as aluminum does.

Cheap binoculars usually don't have any of their glass surfaces coated. As a result they lose up to 50 percent of the incoming light, sharply decreasing the brightness of the image. Meanwhile the light inside the binoculars gets "bounced" between the inner optics, creating a hazy background and a low-contrast image.

Inexpensive binoculars may have some, but not all, of their optical surfaces coated. The number of surfaces coated can range from one to all except two. Binoculars from Japan that are labeled "coated" must by law have one surface coated on both the eye and objective lenses, as well as the prisms.

Moderate to expensive binoculars usually have all air-to-glass surfaces coated, but there is a catch — not all of the optics in all binoculars are made of glass. In the less costly models at this price range, the inner field lens of the eyepiece is sometimes made of plastic. In this case "fully coated" applies to air-to-glass surfaces and, since plastic is not glass, the plastic lenses are commonly not coated.

Cost also influences the thickness of coating, which determines its effectiveness. For magnesium fluoride the optimal thickness is one-quarter the wavelength of the desired light. Manufacturers generally use the wavelength of light the eye is most sensitive to, about 550 nanometers, as a reference. When light passes through a coated surface, most of the green/yellow band goes through but less of the red and blue bands are transmitted, resulting in a magenta reflection under ideal conditions. However, since most glass does not have the theoretically perfect density, the reflection normally ranges from pale blue to blue/magenta.

When cost is a major factor, the time and skill that should go into depositing the correct thickness of anti-reflection coating may be compromised. You can see whether or not the binoculars have been correctly coated by the color of the light reflected from the multiple elements. For magnesium fluoride the reflected color of an incorrect coating can range from pink (too thin) to green (too thick). The reflected color of a correct coat is purple-violet.

Top-of-the-line binoculars often have a more sophisticated type of coating called "multi-coating," which reduces reflection losses to 0.5 percent or less. Multi-coating, as its name implies, consists of several layers of coating, one on top of another. The exact composition, thickness, and other details of multi-coating are generally trade secrets of the maker. The most common type of multi-coating gives a green reflection although, depending on the type of multi-coating, the reflected color can be any of a variety of tints.

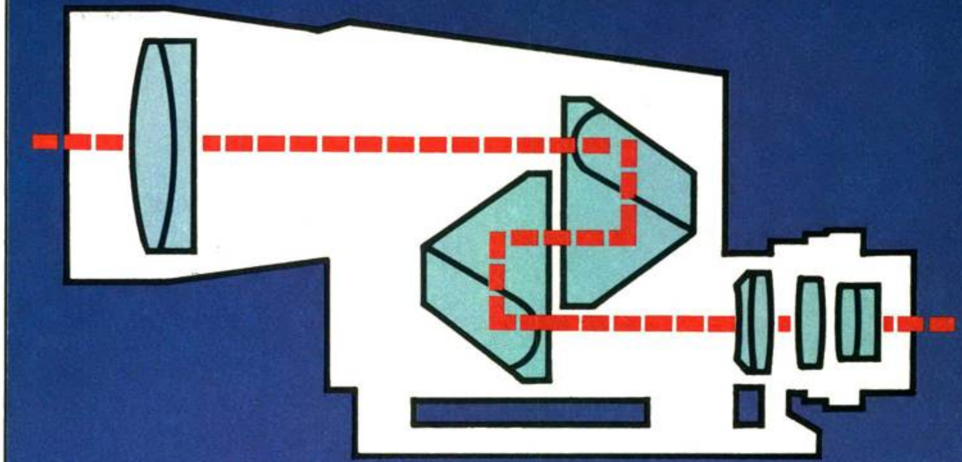
Since an incorrect thickness of magnesium fluoride can cause a green reflection, some unscrupulous dealers deliberately place a poor coating on the outer optics of their binoculars and call it "multi-coating." Other vendors of less expensive binoculars use multi-coatings, but only on a small number of surfaces.

Prisms

The composition and arrangement of prisms is another determining factor of the quality of binoculars. The less expensive products normally use prisms made of a

PORRO PRISM DESIGN

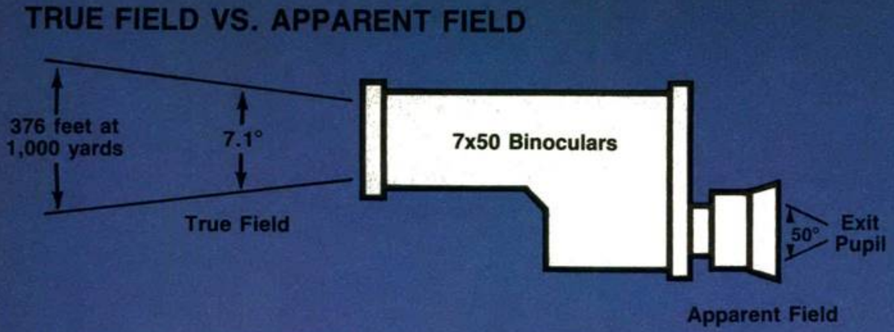
Most binoculars suitable for astronomy utilize the Porro prism design, which is an offset prism arrangement. High magnifications and a wide, three-dimensional field of view are advantages of the style.



1

1. **The German or Z style binoculars are characterized by separate objective and prism bodies.**
2. **The American or B style binoculars have the objectives and prisms in the same body. Photos courtesy of Bushnell.**

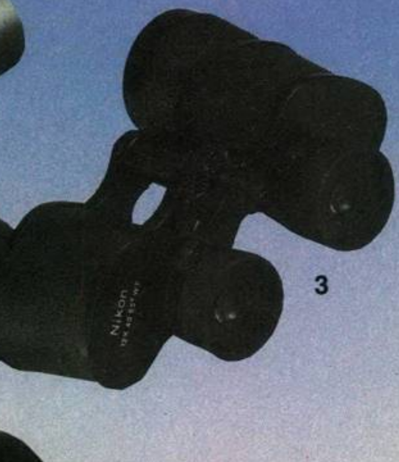
2



1

1. 8x56 Porro prism; 7mm exit pupil. Swarovski America Ltd.
2. 25x150 large binoculars for use with a sturdy mount. These can be fitted with right-angle viewers; 6mm exit pupil. Fujinon, Inc.
3. 12x40 Porro prism center focus; Z style; 3.3mm exit pupil. Nikon, Inc.
4. 11x80 Porro prism center focus; 7.27mm exit pupil. Swift Instruments.
5. 10x50 Porro prism B style with lever focus; 5mm exit pupil. Bushnell.

2



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5

type of glass called BK-7; the better, more expensive binoculars use prisms made from a denser glass called Bak-4. The main difference between these two types of glass is their density, which is indicated by their index of refraction.

There are two types of prism systems: Porro and roof. Most binoculars of astronomical quality use Porro prisms. These are triangular in cross section and are slightly offset in each barrel. The light enters the long, hypotenuse face at one side, reflects from each of the shorter faces, and exits at the opposite side of the long face. Binoculars have two prisms per side so that the light has made four reflections by the time it reaches your eye.

Since there are four reflections in the prisms, there are four occasions when light is lost. This can be seen in the binoculars' exit pupil (the image of the objective seen as a disk just behind the eye lens when the binoculars are held about a foot away). The exit pupil will have a bright "square" with the edges filled out by four darker "shaded" chords — like a square peg in a round hole. Each of the four shaded areas is only three-quarters as bright as the central square. Binoculars with Bak-4 prisms have glass just dense enough to reflect all of the off-axis light and therefore have a uniformly bright exit pupil.

The light loss is not a problem as long as a person is only looking at something bright in the center of the field of view, but if one is looking at something that fills the entire field, especially a dim object, the light loss at the edges can become noticeable.

The roof prisms serve the same purpose as Porro prisms but accomplish it with a different prism construction. A binocular roof prism normally consists of two or three pieces of glass shaped like a house roof and cemented together. This type of prism does not offset the light path, which makes the binoculars more compact.

Given the constraints of the design, roof prism binoculars are not well-suited for astronomy. Because of the prism's shape, one surface is not totally internally reflecting and must have an aluminum coating. As a result about 12 percent of the light that strikes it is lost. In addition, the angle at which the two roof surfaces join must be *very* accurate — about 2 seconds of arc — in order to direct the light in a tight path down the barrel to your eyes. A greater angle than this would degrade the image. In contrast, a Porro prism system can have a total angular error of 10 minutes of arc.

For these reasons, roof prism binoculars are expensive to make. But even the most expensive roof prism models will not be as good for astronomical observing as the Porro prism models.

Field of View

A very important consideration when buying any model is the "apparent" field of view. The apparent field is the angle you see in the eyepiece. (The true field, on the other hand, is the actual angle of sky or terrain that is covered in the apparent field.) The apparent field is approximately the binoculars' true field of view, given in degrees, multiplied by its magnification. The generally accepted labeling conventions call a binocular with an apparent field of 50° "standard"; those with 60°, "wide angle"; with 75° or more, "extra wide angle."

Most people prefer as wide a field as possible, but wide-angle or extra wide-angle units have several drawbacks. Though technically delivering the rated field of view, cheap binoculars have such poor optical quality that they yield a sharp field of only 50° or less. As a general rule only the top-of-the-line models render sharp images close to the edges of their fields.

Another factor that applies to all wide-angle models, regardless of price, is eye relief. Eye relief is the distance between the viewer's eyeball and the eye lens of the binoculars' eyepiece, at which the full field of view is seen. (For the full field of view to be seen, the exit pupil should correspond with the dilation of the dark-adapted pupil, which is between 5mm and 7mm. An exit pupil larger than 7mm means that some of the light will be lost outside of the eye's entrance pupil, no matter what the distance of the eye from the eyepiece.)

The eye-relief distance is fixed by the eyepiece design and is normally rather exact, and the eyepiece designs used in binoculars mandate that the eye relief be fairly short. This short eye relief is adequate for use without eyeglasses, but a person who must wear glasses (or wants to wear sunglasses during the day) is forced to position his eyes where they cannot reach the correct eye-relief point. When a person looks into binoculars with his eyes outside the correct eye-relief distance, the field of view is reduced. This reduction depends on the individual and the design of the binoculars.

The final drawback of wide-angle and extra wide-angle binoculars is that they are heavier than standard units. This extra weight is due to the larger eyepieces and larger housing. Wide-angle binoculars yield breathtaking views of the stars, but without a sturdy tripod, the observer's arms are likely to give out long before his enthusiasm.

What to Choose?

Finally, what type of binoculars are best for you? Although the most frequently recommended type is 7x50s, this may not be the best choice for you.

The important feature of 7x50 binoculars is not just the size and weight of their 50mm objectives — though this is the largest practical size for hand-held binoculars — but rather the size of the exit pupil. A binoculars' exit pupil is easily derived by dividing the diameter of the objective by the magnification. In the case of 7x50s, that value is 7.1mm. This pretty well corresponds to the size of the dark-adapted entrance pupil of the eye, which is about 7mm. However, your eye's entrance pupil does not always open up to 7mm while observing, especially if your site is in the city or the suburbs where the eye cannot adapt to full darkness. In this case 5mm may be as wide as your entrance pupil will dilate. Also, as you age the maximum size of your entrance pupil decreases. A 7mm exit pupil, then, may be a light waster for the elderly person with a smaller entrance pupil.

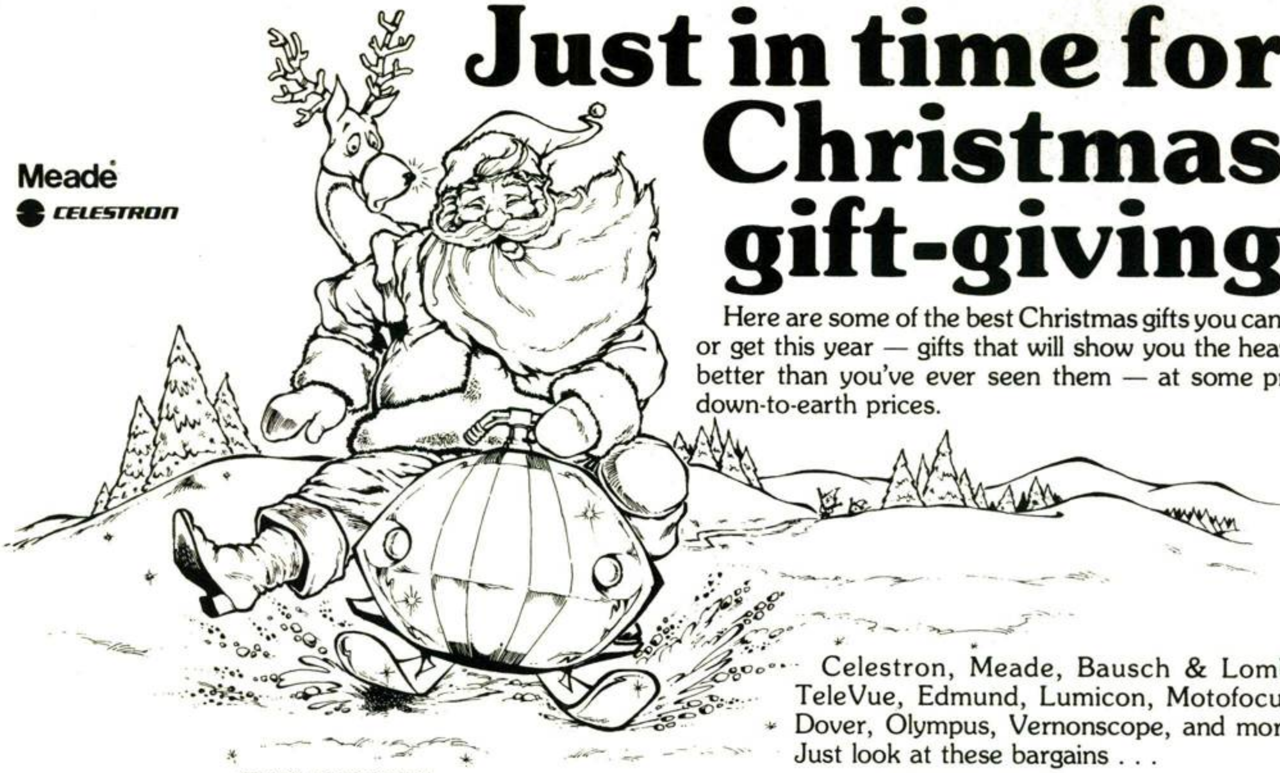
But even with eyes that can fully dark adapt there is very little leeway for varying the eye's position if the exit and entrance pupils are the same size. Some sort of bracing is needed for best results, be it a tripod or an outdoor chaise lounge. A 5mm exit pupil is a better size for most users. Only if you are young and plan to use your binoculars frequently under a very dark sky should you pick an instrument with a 7mm exit pupil.

The binoculars that are probably best suited for general astronomical use are a well-made 10x50 Porro prism model with multi-coated optics. Binoculars fitting this description are expensive, although considerably less costly than the least expensive well-made telescope.

If you observe from an urban area that is badly light polluted and are concerned about the size and weight of your instrument, then 7x35 binoculars are perhaps the most useful all-around type. They are very suitable for general day use as well as for astronomical use. The additional advantage of 7x35 binoculars is that they are the most common and are available in the most models and with the most features.

The main rule is to buy the best instrument you can from an established manufacturer, preferably one that can answer your questions. If you are still in doubt about which model to choose, remember that, like telescopes, good binoculars are not cheap. Too much of a compromise in selecting a good pair may mean too much of a compromise in image quality. The right binoculars can be one of the best investments you'll ever make.

Kendall Morris is an engineer with the Bushnell division of Bausch and Lomb in Pasadena, California. He describes himself as a "casual" amateur astronomer.



Meade

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AstroNews

Evidence Found for Water on Mars

In 1972 planetary scientists examining photographs sent back from Mars by Mariner 9 were astonished to see features that resembled well-preserved dry channels, similar to the water-cut arroyos found in arid regions on Earth. Additional photos sent back by the Viking orbiters between 1976 and 1981 also revealed features resembling islands, sandbars, and shorelines.

Recent interpretations of these features by Jet Propulsion Laboratory planetary geologists suggest that several billion years ago the Martian landscape may have been dotted with rivers, lakes, and seas of water.

The research is described in a paper by JPL geologists Timothy Parker, Dale Schneeberger, David Pieri, and Stephen Saunders, and was presented at the "Symposium on Mars: Evolution of its Climate and Atmosphere" held last July in Washington, D.C.

Research by Parker *et al.* is concerned with determining whether the landforms at the edges of the plains in the Martian lowlands resemble features typically found along lakeshores and oceans on Earth. Parker and his colleagues indicate three sites exhibiting features that would seem to have a water-formed origin: Cydonia Mensae in Mars' northern hemisphere, an eroded mountain chain that, according to Parker, strongly resembles island groups on Earth; Acidalia Planitia, a loose, broken chain of mountain-like "knobs" that could have been produced by water wave erosion; and Deuteronilus Mensae, an area of eroded mesas that may be the remnant of an ancient shoreline.

The lakes and seas in Mars' northern lowlands, says Parker's group, may have formed as the result of massive floods, which subsequently created large Martian channels 2 or 3 billion years ago.

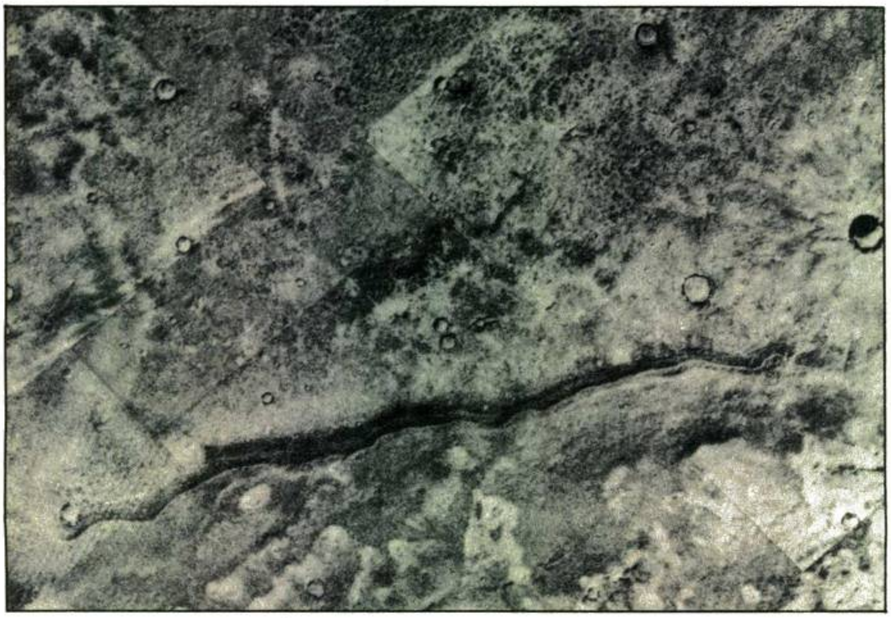
This research bolsters findings presented by scientists last year at NASA's Ames Research Center. According to Bruce Jakosky of the University of Colorado, the Martian poles were once tilted toward the Sun. As a result, the polar ice caps may have changed from a solid to a vapor state during the continual daylight of polar summer. Vapor from the caps would have been carried on Martian winds to the cold equatorial regions, where it would have precipitated as snow.

Gary Clow of the United States Geological Survey reported that the equatorial snowpack could have been heated by trapped sunlight beneath the snow fields. Even if the surface was still cold, water could have flowed beneath this insulating blanket of snow carving the branch-like "valley network" channels of Mars photographed by Mariner 9.

Ice-covered lakes may have existed in the vast Valles Marineris canyon system located just south of the Martian equator, according to astronomer Steven Squyres. Viking photographs of the floor of these complex canyons reveal thin sedimentary layers that appear to have been deposited in liquid water.

This aqueous history contrasts strongly with the geologic conditions on Mars today. Most ice is found in high latitudes, chemically bonded to minerals in the soil, frozen in ice deposits at the poles, or as permafrost beneath the surface. Liquid water cannot exist on the surface because the planet's low atmospheric pressure would cause it to boil away. And in the colder regions, water that did not evaporate would freeze.

This mosaic of high resolution images from Viking Orbiter 2 shows detail that may be the shoreline of an ancient Martian lake or sea in the Deuteronilus Mensae region. The shoreline is the dark linear feature running across the lower half of the photo. The land below the shoreline is a portion of a canyon that may have been partially filled with water 2 or 3 billion years ago. Planetary geologists at the Jet Propulsion Laboratory believe that subsurface reserves of this water were suddenly released, flooding the basin at the upper right of this photo. JPL/NASA photo.



However, some scientists believe the presence of meager amounts of Martian ice nevertheless indicates that liquid water might exist deep within the planet. According to Michael Carr of the U. S. Geological Survey, water could exist half a mile beneath the surface in the pores of Martian rocks where high interior temperatures keep the water in a liquified state.

Both groups were careful to point out that more research needs to be done. The JPL group labeled their concept a hypothesis, stating that the Viking photos lack sufficient resolution to allow detailed study of these enigmatic features. The question of how much of a role water played in shaping the Martian landscape, they said, may not be settled until future Mars missions.

Mission beyond the Solar System Studied at JPL

A spacecraft that could carry a 1.5-meter (60-inch) telescope beyond the solar system is now under study by scientists at NASA's Jet Propulsion Laboratory in Pasadena, California. The main objective of the mission, dubbed the TAU Project (Thousand Astronomical Units), will be to determine distances to stars and galaxies more accurately than is possible from Earth.

By measuring the apparent change in position of a star seen from opposite sides of Earth's orbit, a method called trigonometric parallax, astronomers can measure the distance to stars up to 400 light-years away. This distance, however, represents only a relatively small corner of our own galaxy.

The TAU Project would increase the distance between the two points where measurements are taken from the current maximum of 2 astronomical units to 1,000 AU. By comparing measurements taken on Earth with those made during TAU's journey, astronomers will be able to determine distances to stars in the far reaches of the Galaxy.

JPL astronomers Aden and Marjorie Meinel are directing the TAU Project planning team, which held its first organizational meeting in September. Establishing the scientific objectives of the mission as well as the configuration of the spacecraft is expected to be a multi-year process culminating in a launch early in the next century.

The proposed mission employs propulsion and communications technology that is still on the drawing board at JPL. Three nascent technologies — ion propulsion, megawatt nuclear reactor power sources, and optical laser communications — are the cornerstones of the project and have been under study for several years at JPL.

The megawatt nuclear reactor would electronically accelerate a beam of ions to produce thrust over a ten-year period. Traveling at a speed of over 350,000 kilometers per hour, the spacecraft will complete its 1,000 AU journey in fifty years. (The Voyager spacecraft would take over 300 years to reach that distance.) A laser communications system will send data back to Earth where it can be picked up by receivers on a space station.

The TAU Project is the subject of a special workshop to be held at the January 1987 meeting of the American Astronomical Society in Pasadena, California.

Japanese Rocket Causes August Light Spectacular

The night of August 12 provided an unexpected treat for skywatchers across the eastern United States. Shortly after 9 p.m. EDT a large cloud of glowing gas became visible in the eastern sky. The spectacle was caused by the release of liquid hydrogen from the second stage of a new Japanese rocket launched earlier that day.

A number of observers, many of whom were watching the annual Perseid meteor shower, witnessed the event and provided reports of what they saw. Initially the cloud had a distinct spiral shape with a central condensation. The cloud moved northeast and grew in size, eventually spanning nearly 10°, while the spiral pattern faded. The entire apparition lasted between twenty and twenty-five minutes. Sightings were reported from Maine to Wisconsin and from Ontario to Louisiana.

To Jimmy Witherington of Monroe, Louisiana, seeing the nebulous cloud brought back memories of Halley's Comet. Watching through an 8-inch telescope, he estimated the bluish white point source to be about 0.5 magnitude at an elevation of 20°. A bright silver glow streamed away from it, branching about 4° below the point of origin.

Roberta Burns of Cincinnati, Ohio, described the cloud's shape as a spiraling corkscrew with a central brightness of −1 magnitude. Moving in a northeasterly direction the surrounding cloud continued to grow until it dissipated about twenty minutes later.

Cameron Boyd, observing the phenomenon from Ontario with binoculars, saw a distinct spiral with a point at its center. Five minutes later the spiral shape disappeared with the cloud's expansion, and ten to fifteen minutes later the cloud became too diffuse to be seen.

Bill Tate of Mt. Clemens, Michigan, compared it to M-51's appearance through a telescope. He also took a sequence of 30-second exposures that showed the cloud from the initial central condensation until it had faded to a nebulous glow.

Approximately five hours before the sightings the National Space Development Agency of Japan launched a successful test flight of its new H-I rocket from the Tanegashima Space Center in southern

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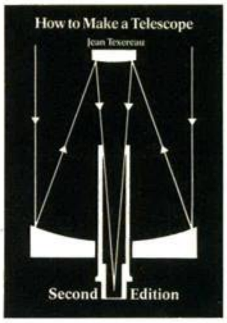

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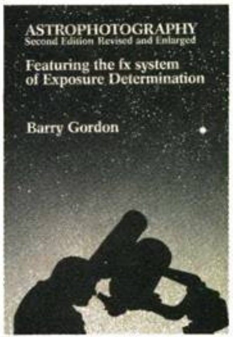
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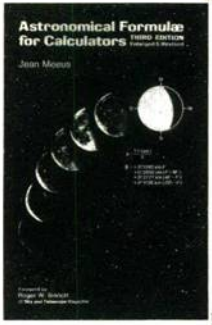

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Japan. It carried an experimental geodetic payload, an amateur satellite for ham-radio operators, and a magnetic flywheel experiment into orbit.

The cryogenic second stage that released the burst of liquid hydrogen is an integral part of Japanese booster capabilities, and as such will be used in future launches. Since the United States is downrange from Japan's launch facilities, similar spectacles may occur in the future.

New Evidence Questions Gravitational Lens Discovery

The announcement earlier this year of the largest gravitational lens ever sighted (AstroNews, August 1986) created quite a stir in the astronomical community. More recent observations, however, have cast doubt on the initial interpretation, and many astronomers now believe that the "lens" is a case of mistaken identity.

A gravitational lens is a massive object that deflects light from a more distant object so that the light appears to be coming from more than one direction. When Edwin Turner of Princeton University and his colleagues presented their evidence for a gravitational lens it seemed compelling: two quasar images located close to each other in the sky had nearly identical redshifts and very similar spectra. However, the real excitement came from the 157-arcsecond separation of the images, a separation more than 20 times greater than that in the largest previously-known gravitational lens.

Because the mass of the lensing object determines this image separation, the object had to have an equally large mass. Something with the mass of an extremely rich cluster of galaxies was distorting our view of the quasar and yet remained invisible. The speculation over the nature of the object included such exotic possibilities as a supermassive black hole or a cosmic string.

But it now appears that the two spectra are not as similar as first thought. The original spectra taken by Turner and his colleagues covered only visible light stretching in wavelength from 4600 to 7500 Angstroms. Peter Shaver and S. Cristiani of the European Southern Observatory in Chile have now extended the wavelength range to 9500 Angstroms in the infrared and have found substantial differences between the two spectra. They reported in the June 5, 1986, issue of *Nature* that two hydrogen emission lines prominent in one spectrum were absent in the other, and concluded that the two images are *actually* separate quasars lying close to each other, possibly in the same cluster.

In the same issue of *Nature*, E. Sterl Phinney and Roger Blandford of the California Institute of Technology support the same conclusion through a statistical analysis. Working on the assumption that

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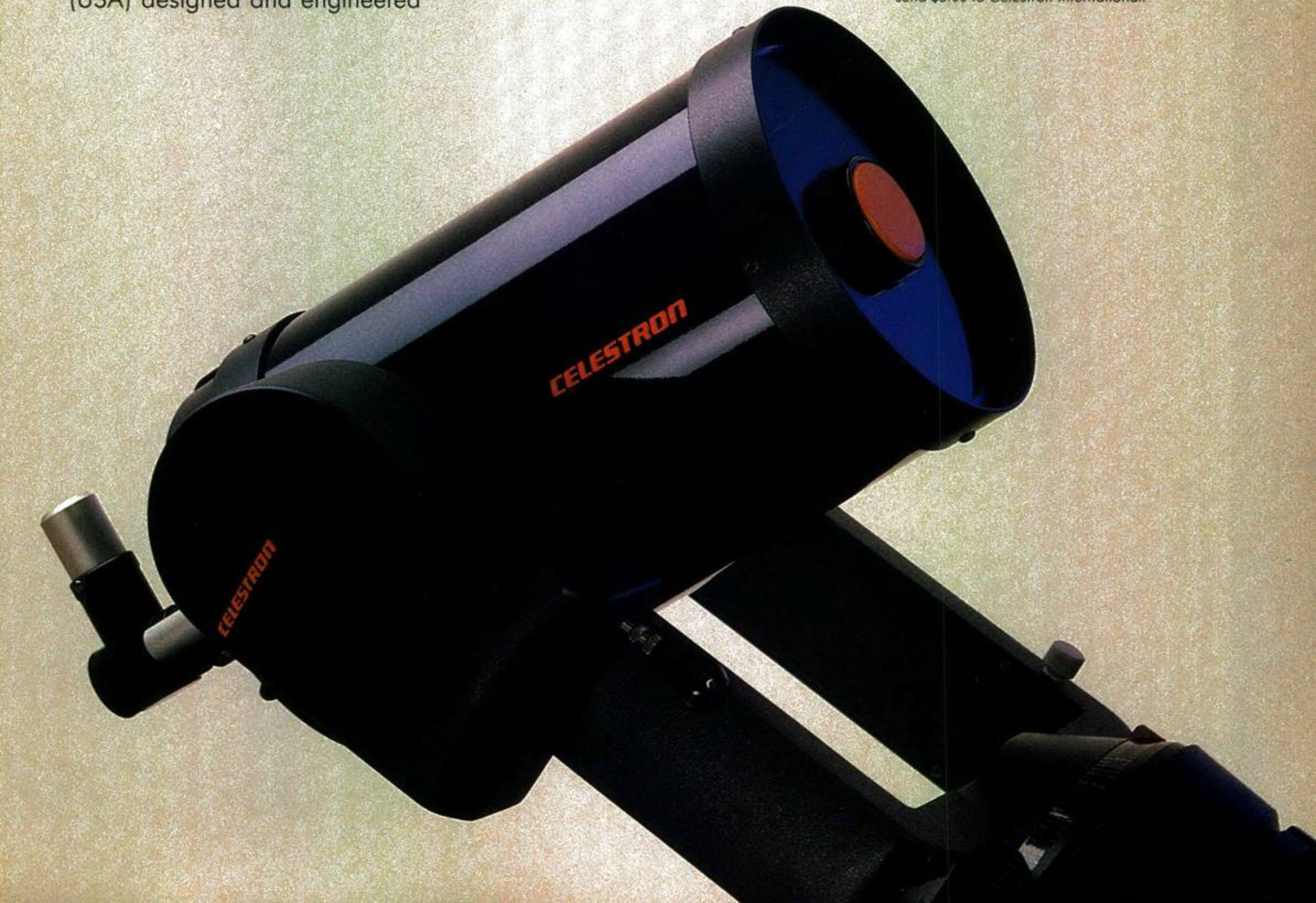

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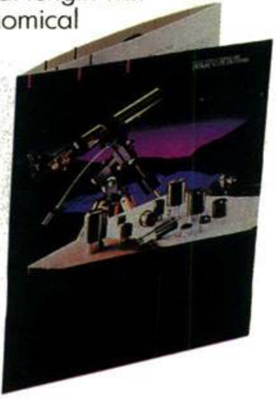


Tele Vue 20 DEXTER PLAZA, PEARL RIVER, NY 10965 (914) 735-4044 quasars cluster in much the same way that galaxies do (for which there is ample observational evidence) and from known quasar densities, they calculated that we should by able to observe one quasar pair with a separation of 157 arcseconds or less.

Although it might seem that the gravitational lens interpretation has been discredited, this is not the case. In any gravitational lens the light forming each image travels a different path to an observer. For a lens large enough to cause the separation seen in this case, the difference in light travel time between the two images could be as much as 1,000 years. Since quasars often exhibit strong variability over much shorter timespans, the observed differences in the spectra could be a result of a single quasar's intrinsic variability.

At present astronomers are divided over the proper interpretation of these quasar images. Some feel strongly that it is a gravitational lens, while others are equally adamant that it is not. The observations that may be able to settle this question are currently underway.

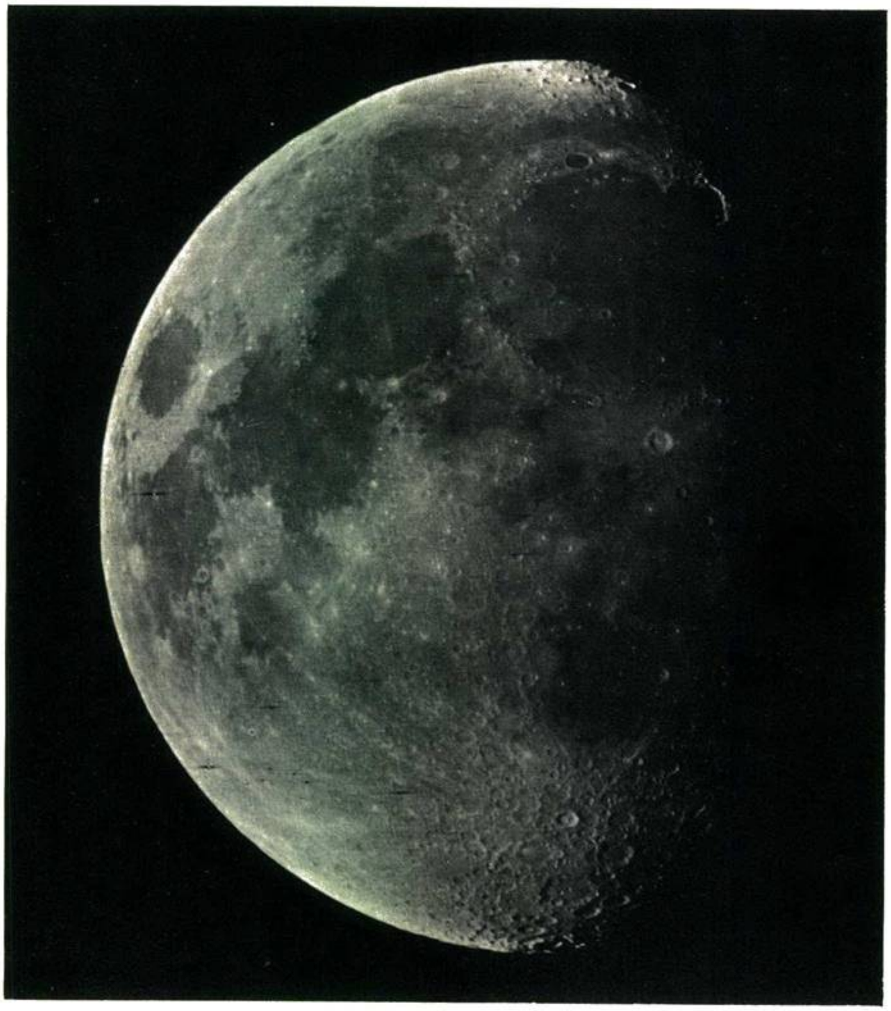
A Telescope to Search for Earth-like Planets

Three University of Arizona astronomers have proposed building a 16-meter infrared space telescope that would allow observers to search for planets like Earth — small objects in close orbit around stars with atmospheres containing oxygen — as far as 10 light-years away.

Arizona's J. Roger Angel, Andrew Y. Cheng, and Neville J. Woolf, reporting in

On the nights of June 16 and 17, 1986, four scientists revived the daguerrotype process as a method of astrophotography using the 24-inch reflector at the U.S. Naval Observatory in Washington, D.C. Noting that "the daguerrotype has no equal in modern photography," USNO astronomer Ted Rafferty, historian Jan Herman, daguerrotype specialist Ken Nelson, and materials scientist Susan Barger photographed the Moon as pioneer photographers Henry Draper and George Bond did 140 years ago.

The astronomers exposed a polished silver-plated copper sheet to iodine and bromine fumes, then inserted it into a specially-made camera. The exposure reproduced below, one of several they produced, is an 8-minute exposure. They developed the photographs over a tray of heated mercury, fixed them in a bath of sodium thiosulphate, washed them, and then gilded the plates in a solution of gold chloride. USNO photograph.



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the July 24, 1986, issue of *Nature*, consider the direct detection of a Jupiter-like planet orbiting the nearest star a formidable task, which may just be possible with the Hubble Space Telescope. Because Earth-like planets would be dimmer and even closer to a star, they would be even more difficult to detect.

The telescope would be too large and flimsy to be constructed on Earth. Instead, it would be made in sections and launched into space for assembly at a space station.

The key to this telescope is an obscuring ring that masks interference from a star's infrared energy, so the image of an orbiting planet isn't lost in its sun's glare. An infrared spectrum of the planet's atmosphere might reveal the distinct signature of oxygen, in the form of ozone, at a wavelength just below where the planet appears the brightest. Such a discovery would provide strong evidence for the existence of life there.

Although Angel said he doesn't expect to see a telescope like this in his lifetime because of the time and cost needed to develop it, he considers it the "be-all and end-all for astronomy. Once it has done its specific job, it has the power to solve astronomical problems far beyond the scope of any presently conceived telescope."

Searching for Fluctuations in the Cosmic Background

Taking advantage of ideal observing conditions at the South Pole, an American science team using a 1-meter radio telescope is searching for fluctuations in the microwave background radiation, the remnant of the Big Bang.

Careful measurements show that this radiation floods the universe and fluctuates no more than 0.000050 of a degree from its current temperature of 2.75 K. This observation is one of the premises of standard cosmological models like the Big Bang, which assume the universe to be a uniform volume of gas expanding equally in all directions.

However, the existence of galaxies is a nonuniform aspect of this symmetry, prompting theorists to suggest that temperature fluctuations should be superimposed upon the background radiation. Such fluctuations would represent the initial clumping of matter into galaxies during the early universe.

Newly-developed instrumentation capable of observing fluctuations ten times smaller than before — down to a few millionths of a degree — will be used for the South Pole experiment. In the past the problem with such sensitive equipment was that the natural radiation from Earth's atmosphere overwhelmed the microwave background radiation. However, previous observations made at the South Pole confirm that the sky noise there is lower than anywhere else on Earth.

To attain the sensitivity needed to detect wavelengths up to 1 millimeter, the radio telescope's receiver will be cooled by liquid helium 0.3 K. Because the telescope will be at the Earth's axis, it will remain in a fixed position and Earth's rotation will do the scanning.

Work on this experiment will be conducted during November and December of this year. The team is directed by Martin A. Pomerantz of the Franklin Institute in Newark, Delaware. Team members include Mark Dragovan, Anthony A. Stark, and Robert W. Wilson, all of AT&T's Bell Laboratories in Holmdel, New Jersey. Wilson, along with Arno Penzias, also of Bell Laboratories, discovered the background radiation in 1965, and were subsequently awarded the Noble Prize in physics for their discovery.

Finding the 'Fifth Force'

Physicists have established the existence of four forces governing the universe: gravity, electromagnetism, the strong force (binding the nuclei of atoms), and the weak force (which contributes to radioactive decay). Dr. Riley D. Newman, a physicist at the University of California, Irvine, has devised a set of experiments to determine if a fifth force causes objects to repel one another at distances between 1 meter and 10 kilometers. Newman's experiments over the last decade have found no measurable influence of such a force at distances less than 1 meter.

If a fifth force exists, it is expected to repel objects, opposing the force of gravity over short distances.

Efforts to detect the fifth force have so far been inconclusive due to its extreme weakness. Observations of the motions of planets and data from Earth-orbiting satellites show that, unlike gravity, the theorized force does not produce significant effects over long distances.

Even if he doesn't find a fifth force at the proposed longer ranges, Newman's experiments will still be considered valuable, because physicists' confidence would be restored in the value they have assigned to the gravitational constant based on experiments conducted at shorter ranges. On the other hand, if this force does exist, it could lead to a reinforcement of the theory of a closed universe.

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November 22
National Space Society Symposium, "America's Space Program: The Last or Lost Frontier," California Museum of Science and Industry, Los Angeles, California. Contact: Leonard David, National Space Society, 600 Maryland Ave., West Wing, Suite 203, Washington, DC 20024. Phone: (202) 484-1111.

January 4-8, 1987
169th Meeting of the American Astronomical Society (professional meeting sponsored by Mount Wilson Observatory and Caltech), Pasadena, California. Contact: AAS, 1816 Jefferson Pl. NW, Washington, DC 20036.

January 29-February 1
Third Annual Winter Star Party (sponsored by the Southern Cross Astronomical Society), Everglades National Park, Florida. Contact: Tippy D'Auria, 1051 N.W. 145 St., Miami, FL 33168. Phone: (305) 685-6001.

February 12-14
Automatic Photoelectric Telescopes II (Fairborn IAPPP Symposium), Apache Junction, Arizona. Contact: Russell M. Genet, Fairborn Observatory, 1357 N. 91st Pl., Mesa, AZ 85207.

February 21-22
American Workshop on Cometary Astronomy (sponsored by the International Halley Watch), Jet Propulsion Laboratory, Pasadena, California. Contact: Comet Workshop, International Halley Watch, 169-214 Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109.

March 14
Astrophoto VII (symposium on amateur astrophotography, sponsored by Ventura Co. Astronomical Society and Orange Co. Astronomers), Moorpark College, Moorpark, California, at 8 p.m. Contact: VCAS/Astrophoto VII, P.O. Box 982, Simi Valley, CA 93062.

April 23-25
Middle Atlantic Planetarium Society (annual meeting), Centerport, New York. Contact: Vanderbilt Planetarium, Little Neck Rd., Centerport, NY 11721.

May 9
14th Annual Astronomy Day. Contact: Gary E. Tomlinson, Astronomical League, Chaffee Planetarium, 54 Jefferson S.E., Grand Rapids, MI 49503.

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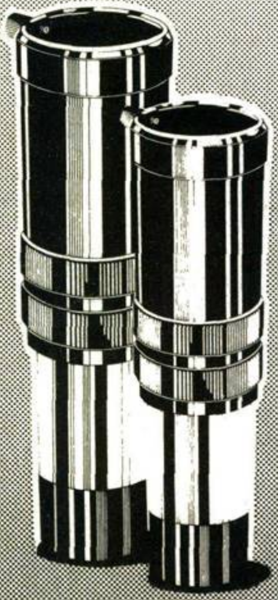

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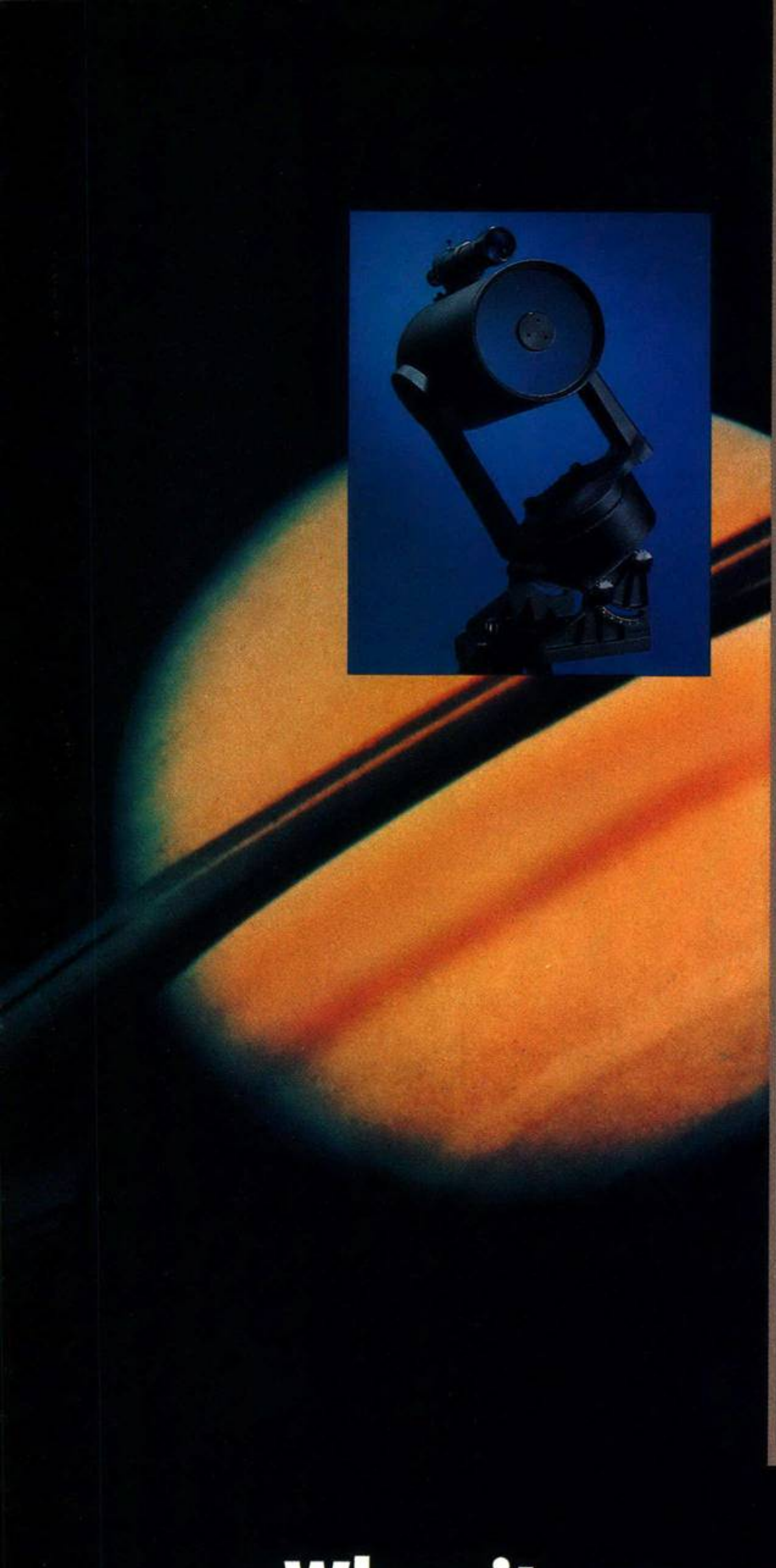

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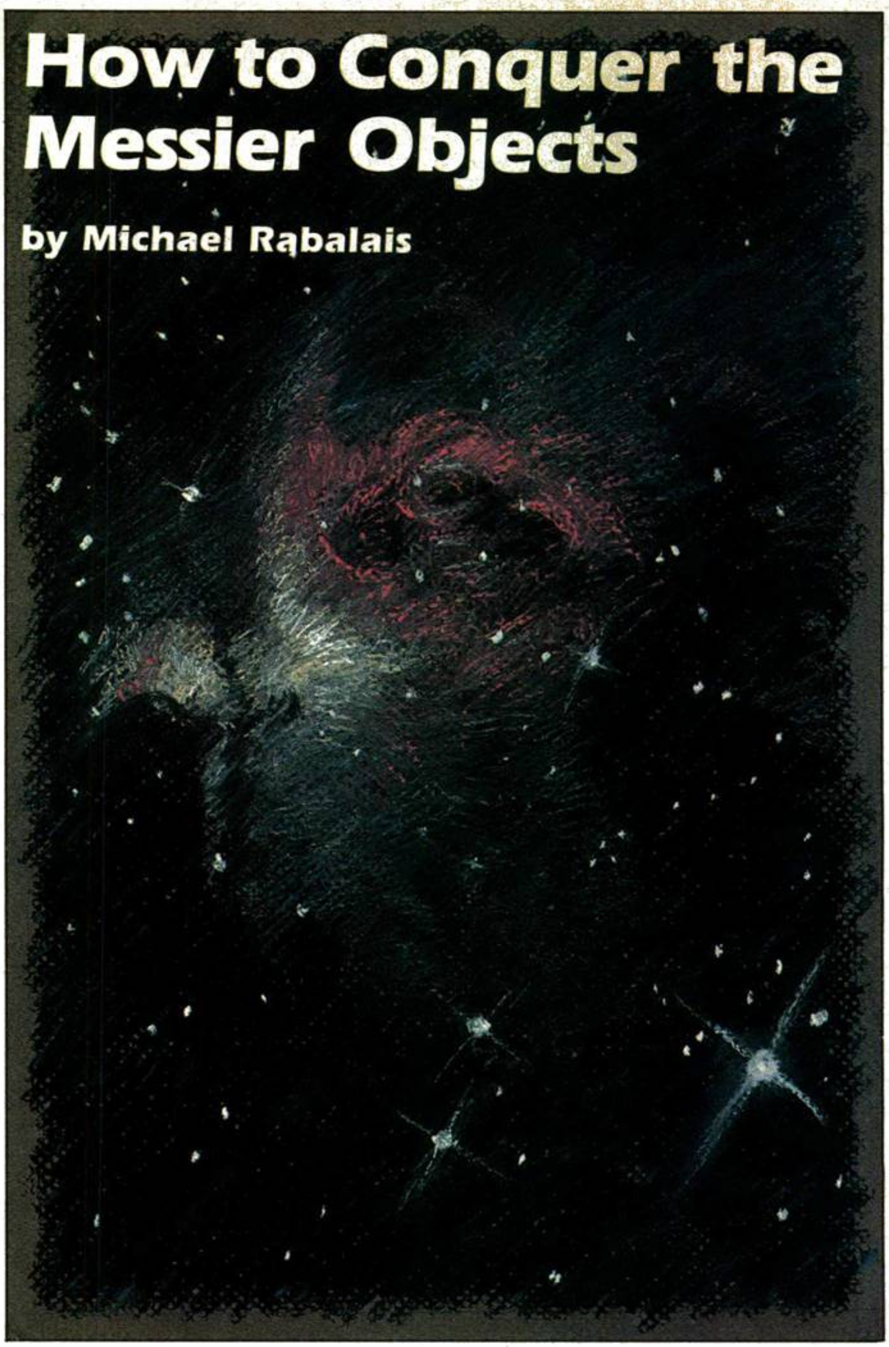
How to Conquer the Messier Objects

by Michael Rabalais



Illustrations by Keith Ward

It's midnight under a dark, starry sky. I'm outside getting ready for a wonderful night of observing galaxies, clusters, and nebulae. My new telescope is my only companion; I can't wait to put it through its paces and see how it performs.

I first look for the Ring Nebula (M-57) in Lyra, since it's bright. I scan the area and don't see anything fuzzy, get lost a couple of times, and go back. I scan some more. Where is it? I've looked exactly where it's supposed to be for half an hour and can't find anything but stars. Are my star charts wrong? Why can't I see the Ring's bright color immediately? Do I need more magnification? I'll bet if I had that 500x eyepiece I saw at the store I would have found it. Finding Messier objects must be easier than this!

This sad story of my first attempt at finding the Ring Nebula almost led me to lose interest in observing the Messier objects — those 107 faint, fuzzy objects catalogued by the French comet-observer Charles Messier late in the eighteenth century. (Messier compiled his list to avoid confusing the stationary objects with comets, which have similar appearances but move across the sky.) With the Moon and planets to observe, I rationalized, I would be busy for years. But in the end (thankfully) I couldn't convince myself to give up on deep-sky objects. The fuzzy patches of light may be tricky to find, I reasoned, but they had much to offer once centered in my eyepiece. The lure of spotting galaxies and far-away clusters of suns was too strong to resist.

After reading all of the observing manuals I could get my hands on, I set out again to discover my first Messier object. To my dismay, I still couldn't find one. My blank observing logbook continued to wait for its first entry.

I began asking myself, "Is something wrong with my telescope? Am I the only one in the world of astronomy who can't find M-13 in Hercules?" One night, that of my birthday, I finally found some answers.

I stepped outside early in the evening to check the sky. At least a million stars were visible, I thought. The Moon was just a slim crescent in the west and wouldn't significantly hinder observing. After I brought my 8-inch telescope outside, my wife presented me with a birthday gift, a 50x eyepiece. I took it from her like she had handed me a skunk. I *knew* that it was too weak for deep-sky observing, but maybe, I thought, it could be traded for a suitable one. She watched me as I opened it, so I smiled the best I could, placed it in the telescope, and let her look at the Moon.

"Oooh, look at it!" she wailed. "This is the best view yet! Look at how bright it is!" I tried to pry her away, but she gazed at the lunar crescent for at least five minutes. When I finally peered into that useless, low-power eyepiece, I wanted to let out a yell. The detail was astonishing! Mountains, rilles, craters — everything was bright and clear. This was the answer I was looking for, and judging by the crisp seeing and clear transparency, I thought, "Tonight I will find a Messier object!"

I snatched my observing logbook, which was still empty, and headed back outside to hunt down that splendid troublemaker known as the Ring Nebula. I knew to look between the two southernmost stars in the small but bright constellation Lyra.

After searching for about two minutes, an unrecognizable object came into view. It was faint and colorless and larger than a star. The more I peered at it, the more confused I became. But once the object was sharply focused, its nature became apparent — it was the Ring Nebula.

I was excited and confused. Then I was confused and excited. At last my logbook had an entry. But where were the colors I had seen in photographs? Why did the Ring appear so faint and gray *tonight*, when I wanted to observe it? Maybe something really was wrong with my telescope.

Well, I've seen many more Messier objects since that first night of discovery and have grown accustomed to how the patches of light appear to the eye, which is not how they appear in long exposure, super-duper, hypered observatory photographs. And there wasn't anything wrong with the telescope, only with its user.

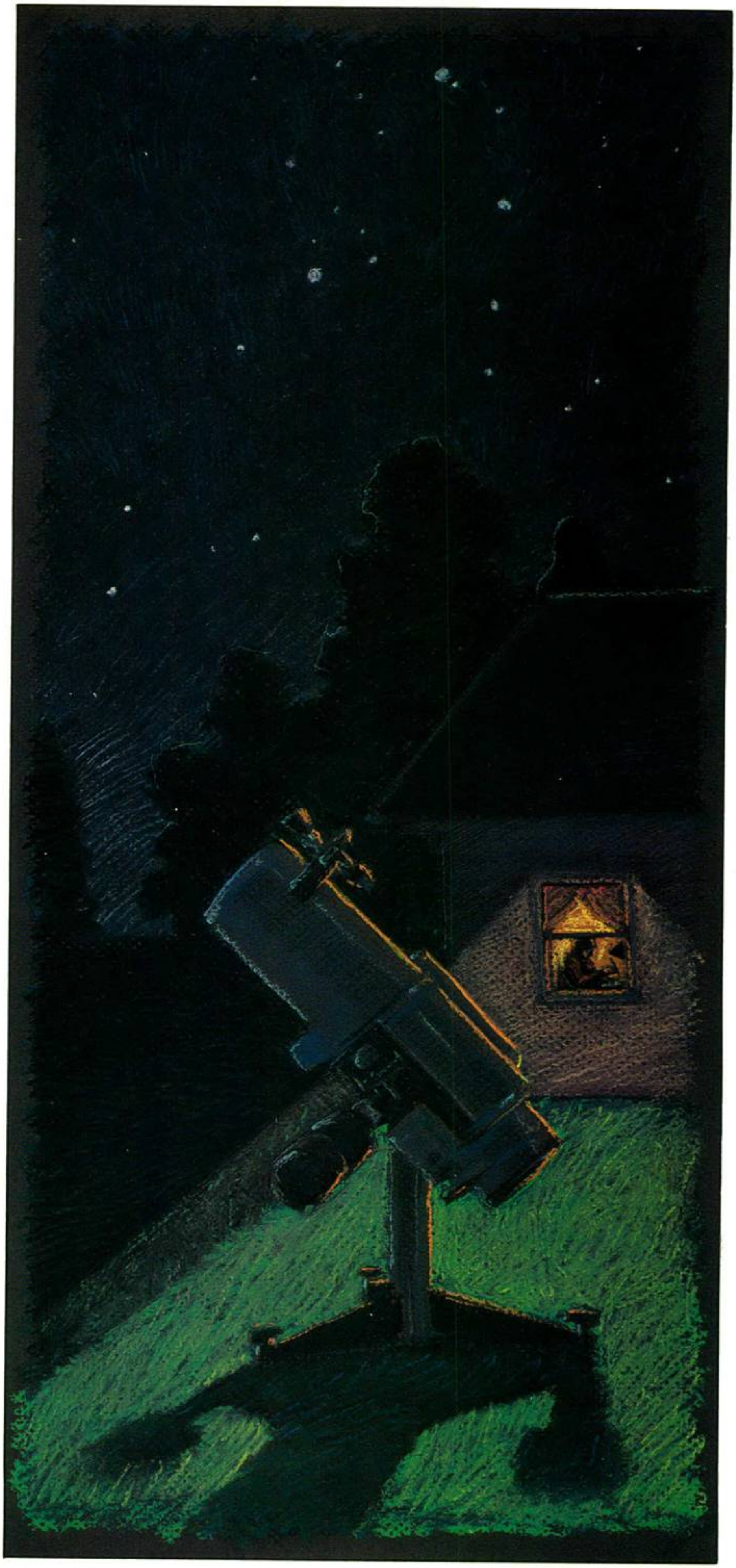
After observing more and more deep-sky objects, I've filed away some useful hints for finding otherwise elusive clusters, nebulae, and galaxies. Contrary to what many observers think, success in spotting deep-sky objects comes mainly with practice. It isn't critical how large your telescope is since even a 2-inch instrument is capable of showing all the Messier objects, unless you use it from an urban area. Your diligence and enthusiasm will go a long way toward refining your ability to find faint objects.

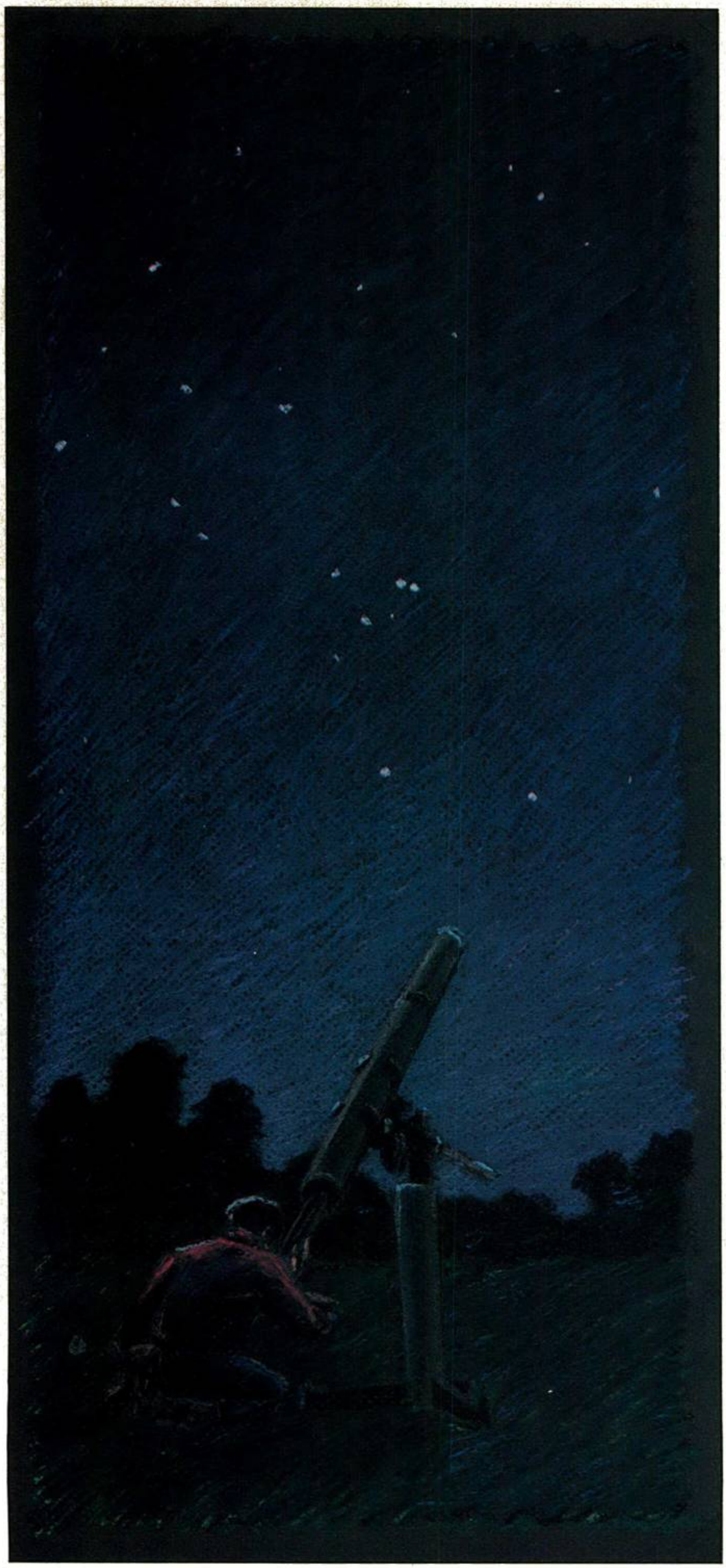
The first step should be to prepare your telescope for observing. Just as you can't see well with a dirty car windshield while driving, you can't see well if there's a dirty mirror in your scope. Try to keep everything — mirrors, lenses, and eyepieces — free of dust and dirt by carefully following the manufacturer's instructions. Remember that the glass itself and especially the coatings are very fragile and can be ruined easily if not cleaned delicately enough or with a proper solution. Compressed air canisters sold at photo stores or solutions containing water, detergent, and an alcoholic solvent — coupled with very gentle wipes using a smooth, soft cloth — will keep your optical surfaces sparkling clean.

Checking your optics for proper collimation — making sure mirrors and lenses are precisely aligned internally — is imperative. If the scope's primary and secondary mirrors aren't well-aligned, the telescope will show you distorted star images. The collimation procedure varies widely depending on what type of telescope you have, so check your owner's manual for instructions. Believe me, the ten or twenty minutes you spend in collimating the telescope correctly when it needs realigning will reward you tenfold in sharp images while observing.

It's also important to give your scope time to cool to the outside temperature before using it. This will eliminate air currents in the tube produced by thermal instability, which would play havoc with the star images you'd see in the eyepiece. The amount of time required to equilibrate your telescope depends on its type. An open-tubed Newtonian reflector adjusts relatively quickly, but the closed-tube designs like Schmidt-Cassegrains require significantly longer time periods.

Once you have your telescope outside and cooling, you need to make your game





plan back inside. In addition to your scope, you'll need a few more items to find Messier objects. First, use the center spread Star Dome map in ASTRONOMY to show you which constellations will be up tonight. From this you can decide what areas of sky you'll need to concentrate on and pick some target objects. (Keep in mind that the higher an object is in the sky, the better your chance of seeing it.) You'll also need a good star atlas like *Sky Atlas 2000.0* to give you a more detailed guide to the section of the sky near the Messier object you're hunting. Armed with this "map of the jungle," you can zero in on the object using your telescope's finder scope and bright stars that happen to lie near the object you're hunting.

A low-power eyepiece is a critical asset to deep-sky observing. Most star clusters and nebulae are large objects compared to, say, planets. But they are very faint and you need to get the brightest images possible to easily find them. A low-power eyepiece not only maximizes the field of view, allowing you to see large objects, but maintains the brightest image possible, making it relatively easy to see inherently faint objects. If you have an 8-inch telescope, an eyepiece yielding 40x or 50x should do nicely. For a 6-inch scope, 30x or 40x will do. You can use even lower power eyepieces, but the practical limit is essentially four times your telescope's aperture.

When you choose a low-power eyepiece, beware of the extra wide-field varieties unless they're of top quality, fully coated, and corrected. The terrible images and poor light transmission produced by some of the bargain brands are headaches you don't need.

With your scope and accessories ready to go and your objects chosen on the star chart, it's time to go outside and check the condition of the night. First, see if the stars appear to be "twinkling." If so, that indicates an unsteady atmosphere, or poor seeing. If the stars appear relatively steady, it's likely to be a good night. In addition to waiting for good seeing, you should try to observe when the sky is very dark, or transparent. This will give you the maximum amount of contrast between faint objects and the sky.

Now that you're ready to hunt down a Messier object, what should you look for? It's funny that most of the information I've read about locating deep-sky objects said they wouldn't be as bright or vivid as their photographic likenesses, and that there wouldn't be much visible color. The books didn't describe what the objects would look like, however. I had to discover that the hard way.

With few exceptions, Messier objects are very dim. Open clusters are loose, random accumulations of stars formed together in the spiral arms of our Milky Way. Several, including M-6 and M-7 in Scorpius, M-25 in Sagittarius, M-39 in Cygnus, and M-45 in Taurus, are bright and fairly easy to locate. Globular clusters are huge balls of suns lying at such great distances that they often appear like unresolved disks of nebulosity with a few faint stars scattered across the field. Globulars are fainter than open clusters in general, but M-4 in Scorpius, M-13 in Hercules, and M-22 in Sagittarius are bright examples.

Nebulae vary greatly in size, shape, and brightness, but generally they are all difficult to observe. The Orion Nebula (M-42) is a splendid exception, being the brightest nebula visible to Northern Hemisphere observers. Galaxies also vary considerably in size and brightness, but several — including M-31 in Andromeda, M-51 in Canes Venatici, and M-81 in Ursa Major — are easy marks for small scopes.

When the sky is dark and steady, begin your search. First look through your telescope at a few stars to see if the instrument is equalized to the outside temperature. If "heat waves" distort the images, wait a while longer. Remember not to confuse unsteady images caused by a cooling telescope with a generally unsteady atmosphere.

Now take out your star chart and, using a flashlight dimmed with a red filter or brown paper bag, look at the target area. Find a bright star nearby in your finder scope and slowly and carefully move toward the area of the Messier object by "hopping" from star to star. A helpful hint is to make imaginary patterns out of the stars you see on the chart and the corresponding ones in the sky. If you say, "I have to jump from the bright star over to the left to two little triangles of faint stars, then move down to a little pair, and then I'm there," it's relatively easy with some practice to become adept at finding faint objects.

When I'm looking for a globular for the first time, I move the scope gently in the general area of the cluster, then watch for the slightest movement or entry into the field of a nonstellar object. Look for a small, faint gray cloud that looks like a "fuzzy snowball" made up of stars. Once you've centered it in the eyepiece, focus carefully and see if you can resolve any parts of the cluster. Give yourself some time to examine the cluster's shape, size, and any color it may exhibit. When you're satisfied, insert your next highest power eyepiece and see if the view is improved. Don't be afraid to use more magnification once you've found an object, but when you increase powers to the point where the image becomes soft, back off.

If you're going for galaxies, slowly scan the target area looking for a blurry or fuzzy star. Stars will appear as sharp points of light, but no amount of focusing will bring a galaxy to a point. Once you find it, look carefully and use averted vision — glancing off to the side of the field — to pick out subtle details you might not see directly. Insert a higher-power eyepiece and check for signs of any spiral structure, the appearance of the nucleus, and any satellite galaxies in the field.

Excellent conditions are needed to successfully hunt for most nebulae. They appear as dim, almost colorless patches of light. Whether you're searching for emission nebulae (gas clouds excited to ionization by hot stars), or reflection nebulae (gas and dust clouds shining by reflected starlight), look for a soft glow that will usually be circular. Use averted vision for seeing subtle details in the nebulosity. Most importantly, have patience with nebulae — most of them are exceedingly faint and require an especially transparent night.

If you can't seem to locate an object after searching for some time, it may help to step back from the scope and take a look at where it's aimed. You'll be astonished sometimes at how far off you can get while scanning around for a target. Knowing the bright stars in the area of an object certainly helps to keep you in the right place. Keeping notes about your observations will help you find the object the next time.

Although at first you may think that it will be difficult to track down Messier objects, it really isn't. The only guarantee I'll make is that every object you see will seem more beautiful than any photograph of it could be because you have captured it with your own telescope. What more could a budding deep-sky observer ask for?

Michael Rabalais is a semi-professional photographer from Lafayette, Louisiana, who has been an avid deep-sky observer for over a decade.

Reference Books for Deep-Sky Observers

The following reference works provide information essential to successful deep-sky observing.

Astronomical Objects for Southern Telescopes, E.J. Hartung. Cambridge University Press, 1984. First published in 1968, *Astronomical Objects* includes a classic set of descriptions for hundreds of deep-sky objects lying in the southern sky. Many of the objects are also visible from the Northern Hemisphere.

Atlas of Deep-Sky Splendors, 4th ed., Hans Vehrenberg. Cambridge University Press, Sky Publishing Corp., and Treugesell-Verlag, 1983. This book contains seventy-six Schmidt camera photos made by the author showing numerous deep-sky objects, most at the same scale. Also included are data on the brightest objects pictured and a selection of observatory photographs.

The Bedford Catalogue, William H. Smyth. Wilmann-Bell, Inc., 1985. This is a reprinting of the deep-sky observing catalogue from Smyth's *Cycle of Celestial Objects*, published over 140 years ago. It contains many historic notes and illustrations made by this famous English observer.

Burnham's Celestial Handbook, (3 vols.) Robert Burnham, Jr. Dover Publications, 1978. A massive constellation-by-constellation listing of double stars, clusters, nebulae, and galaxies, this reference work contains a mountain of information, mostly from the 1940s and 1950s.

The Cambridge Deep-Sky Album, Jack Newton and Philip Teece. Cambridge University Press and AstroMedia Corp., 1983. The *Cambridge Album* is a collection of color photographs of deep-sky objects all made at the same scale, with accompanying information about each bright object in the photos.

Celestial Objects for Common Telescopes, vol. 2, Thomas W. Webb. Dover Publications, 1962. A reprinting of Webb's classic work first published in 1859, this book contains fanciful descriptions of many objects. Colors are given for numerous double stars.

Deep Sky magazine, David J. Eicher, ed. Quarterly. Kalmbach Publishing Co., 1982–. *Deep Sky* features articles by and for observers on specific objects, observing techniques, and astrophotography. Departments cover double and variable star observing, book reviews, and research news. The magazine is illustrated with photographs and sketches of clusters, nebulae, and galaxies.

The Messier Album, John H. Mallas and Evered Kreimer. Cambridge University Press and Sky Publishing Corp., 1978. The *Album* contains a photograph and sketch for each Messier object.

Sky Atlas 2000.0, Wil Tirion. Twenty-six fold-out charts in spiral wire binding; Cambridge University Press and Sky Publishing Corp., 1981. This atlas shows stars down to about magnitude 8, and plots some 2,500 deep-sky objects visible in small and medium-size telescopes. It's a must for deep-sky observers.

Sky Catalogue 2000.0, vol. 2, Alan Hirshfeld and Roger W. Sinnott, eds. Cambridge University Press and Sky Publishing Corp., 1985. A compendium of data tables, this work is an up-to-date source of magnitudes, sizes, colors, etc., for thousands of deep-sky objects.

Webb Society Deep-Sky Observer's Handbook, (5 vols.) Kenneth Glyn Jones, ed. Enslow Publishers, 1979-82. Each volume in the Webb series contains a discussion about the physical and observational aspects of deep-sky objects and a group of telescopic sketches.

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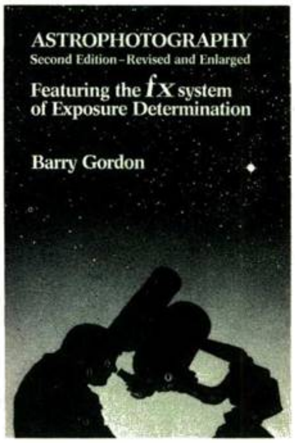
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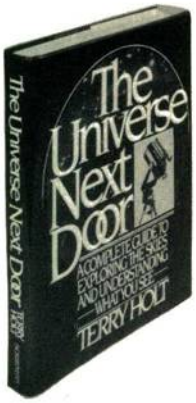
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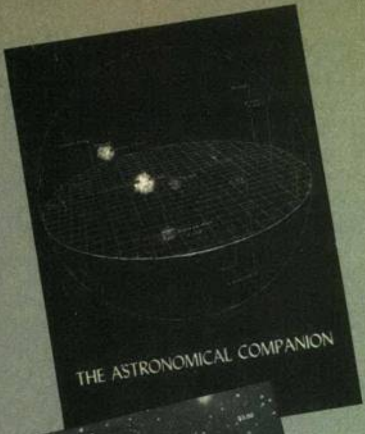
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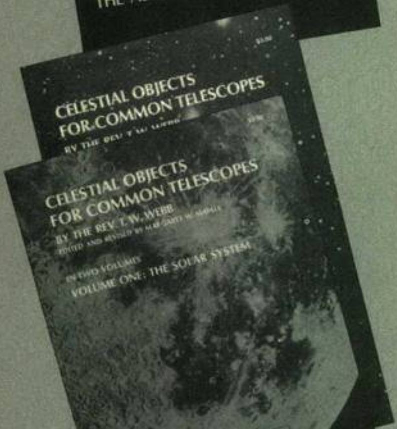
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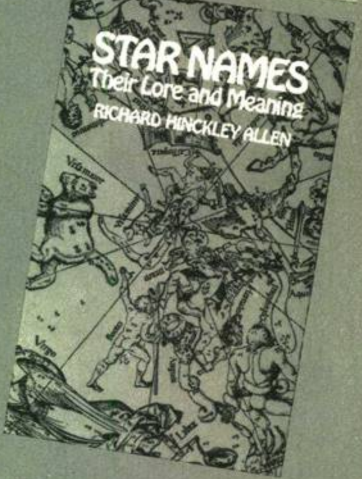
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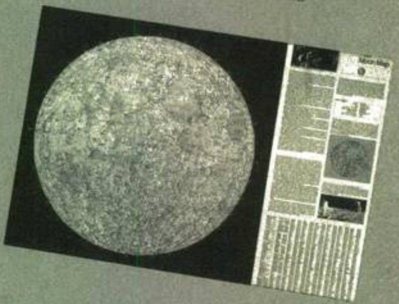

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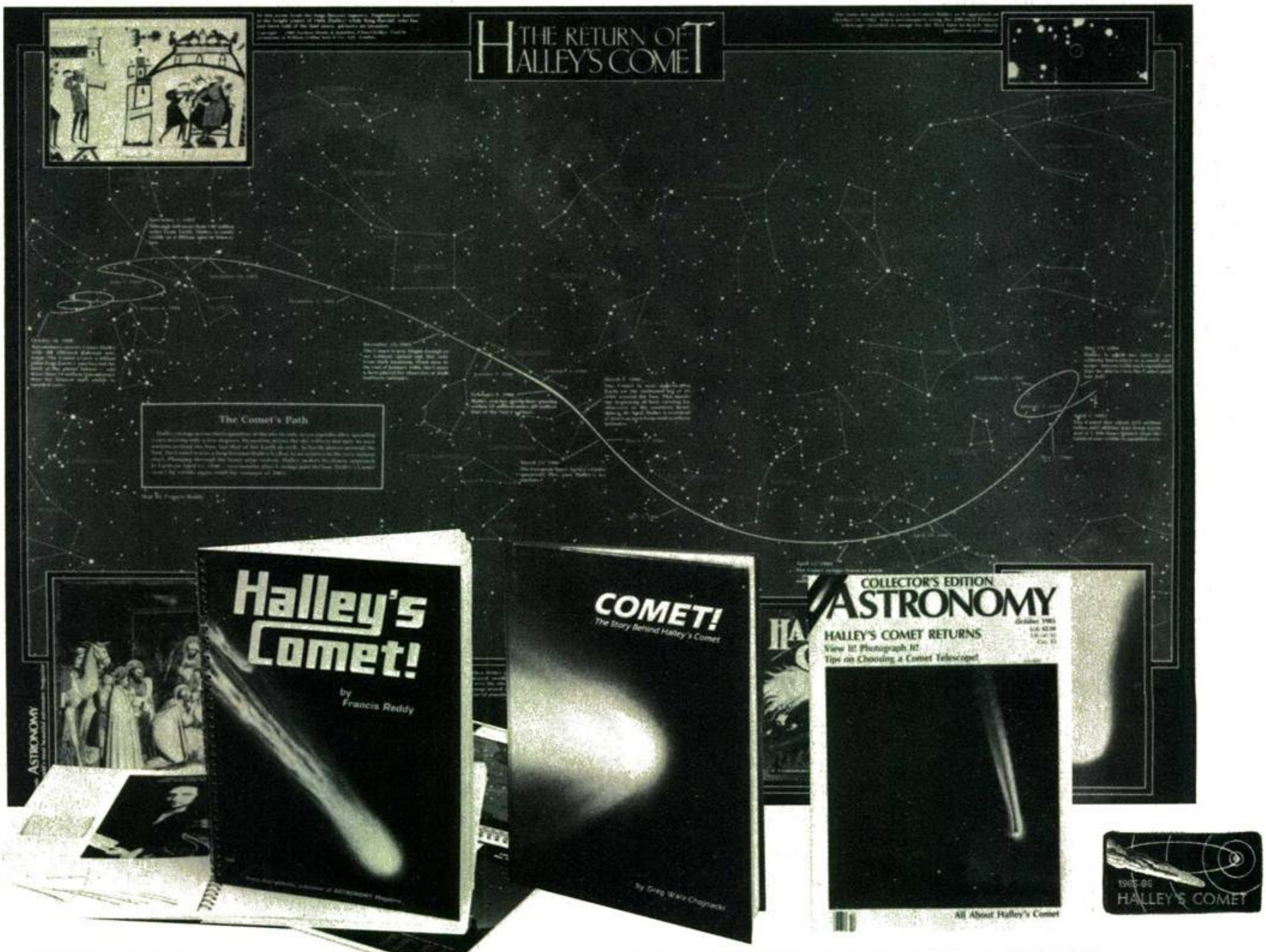
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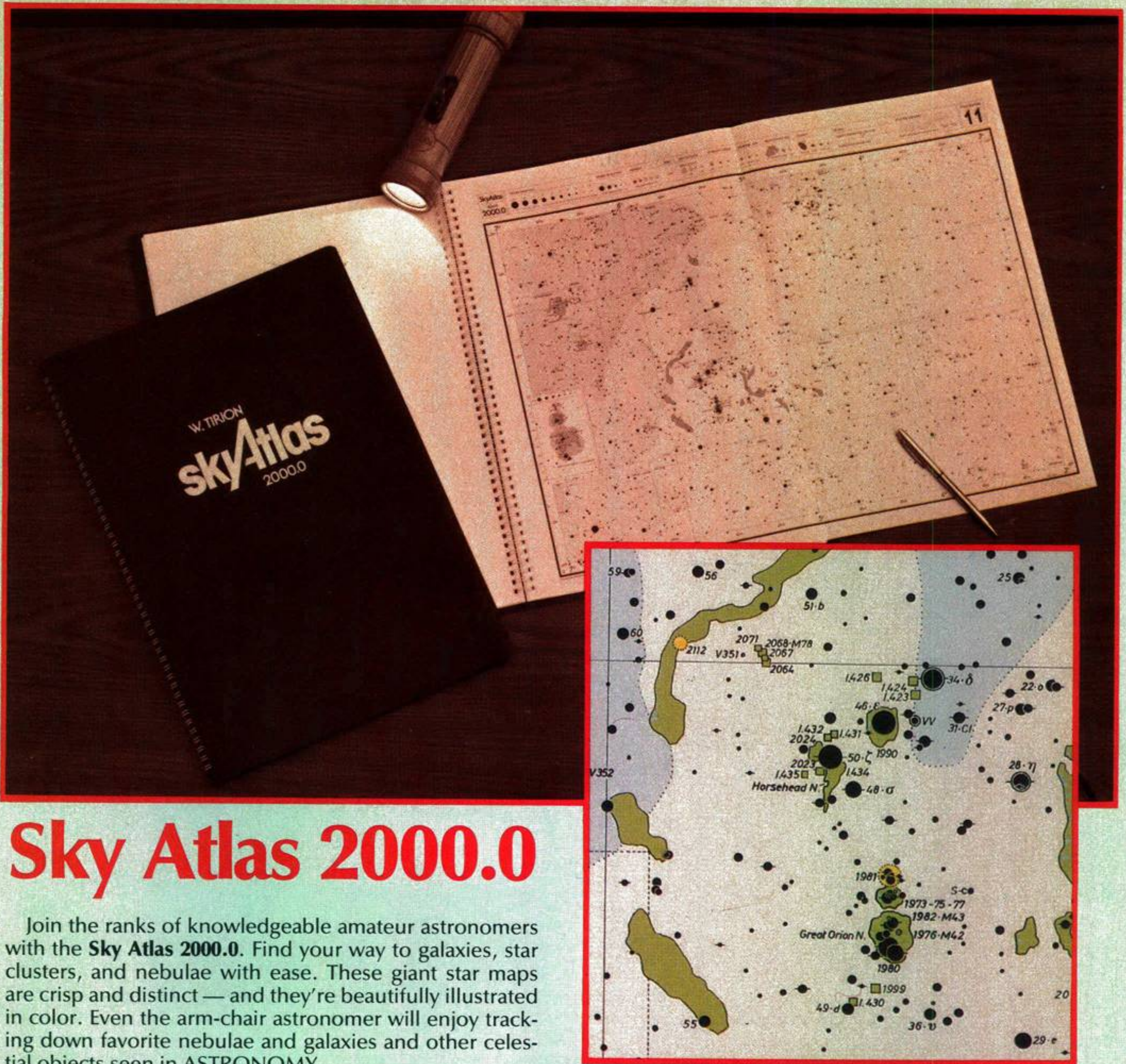
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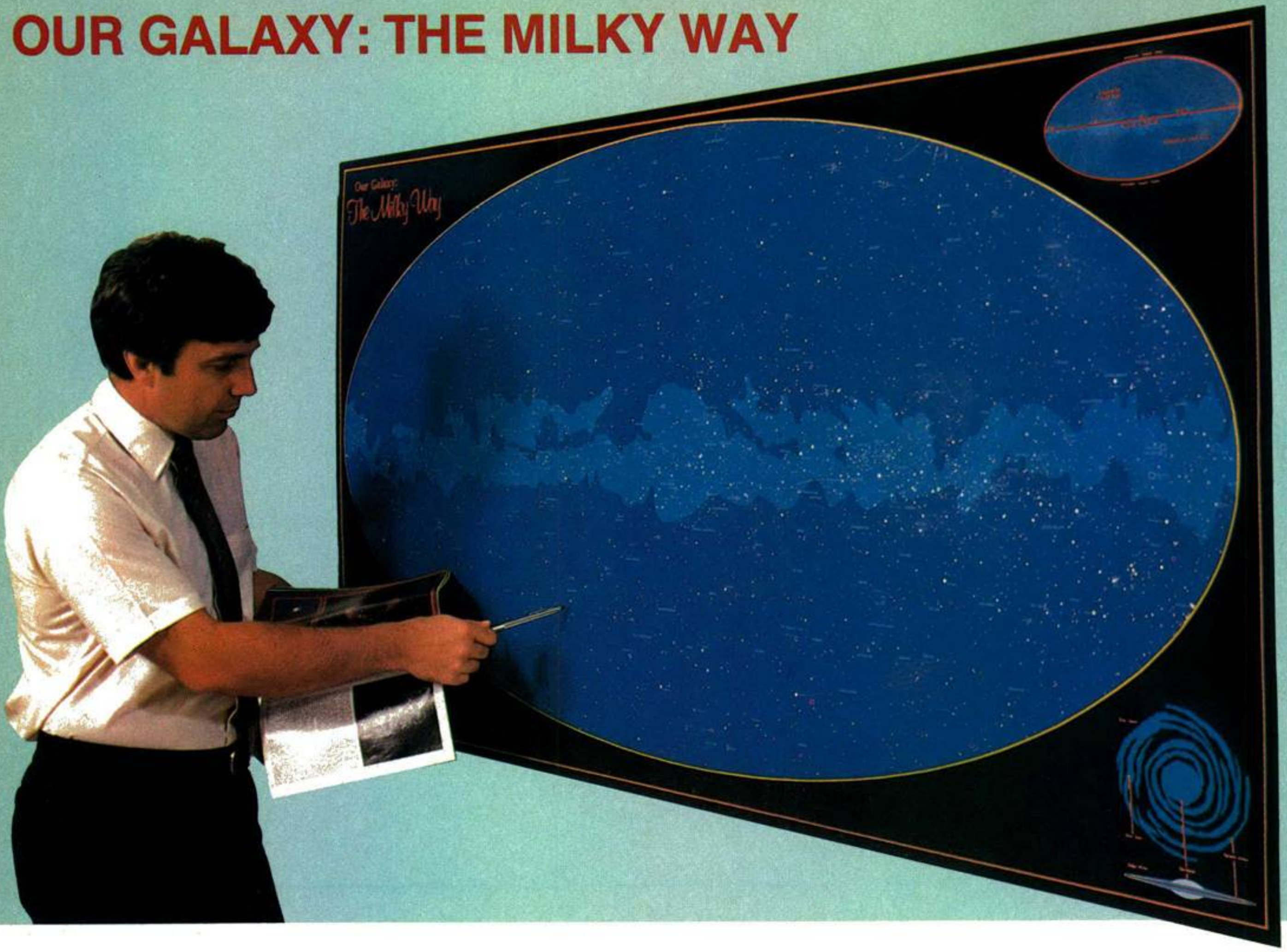

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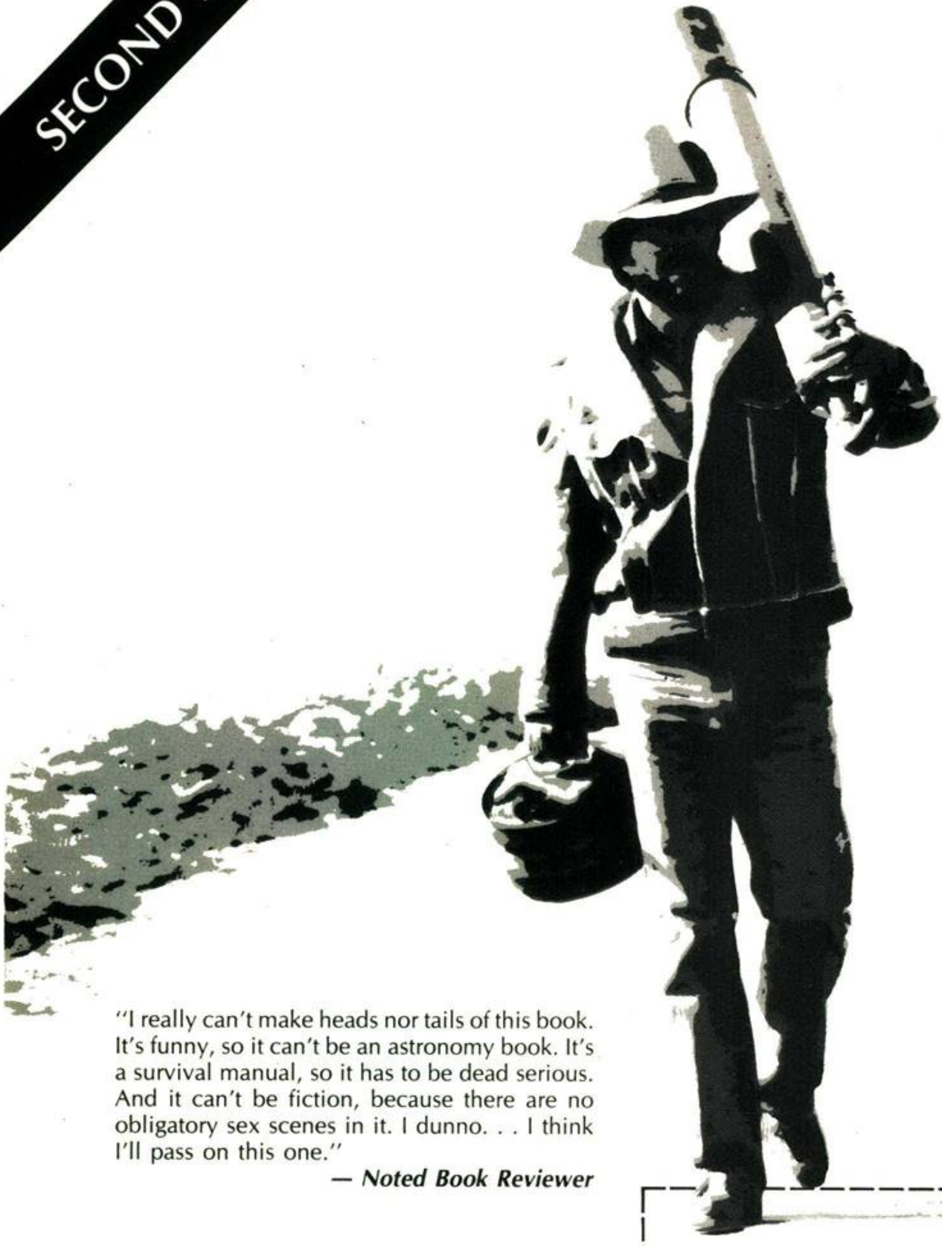

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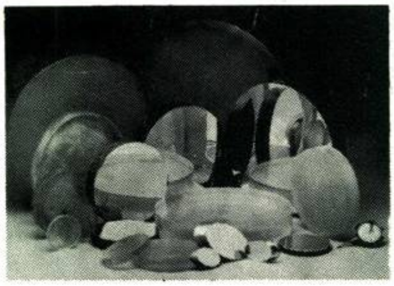

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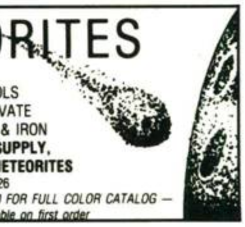

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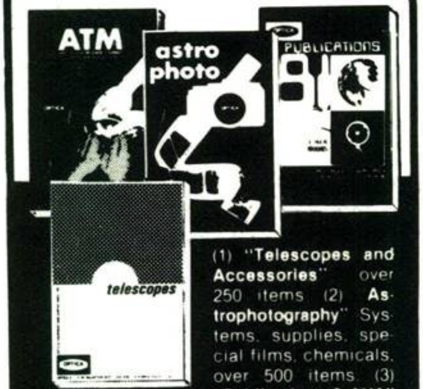

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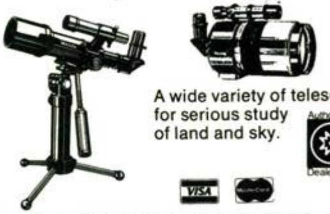

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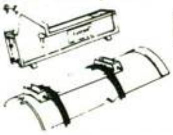

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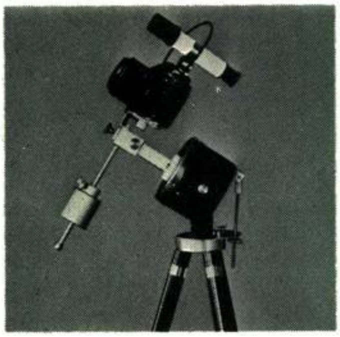

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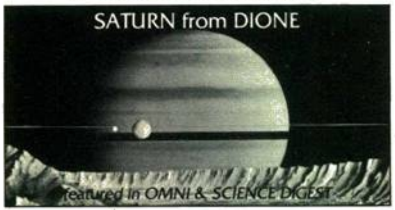
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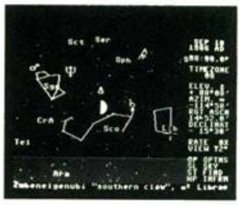

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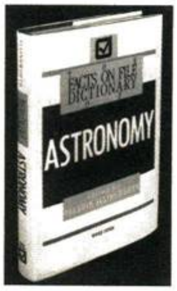

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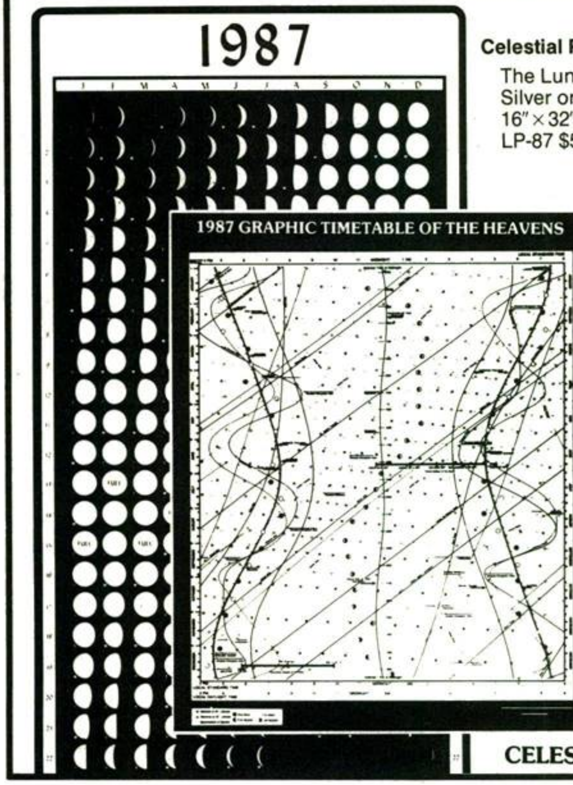

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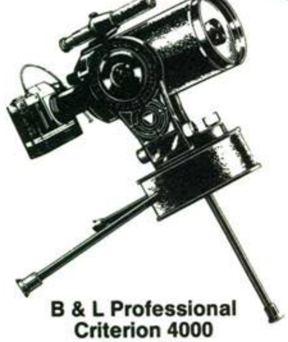

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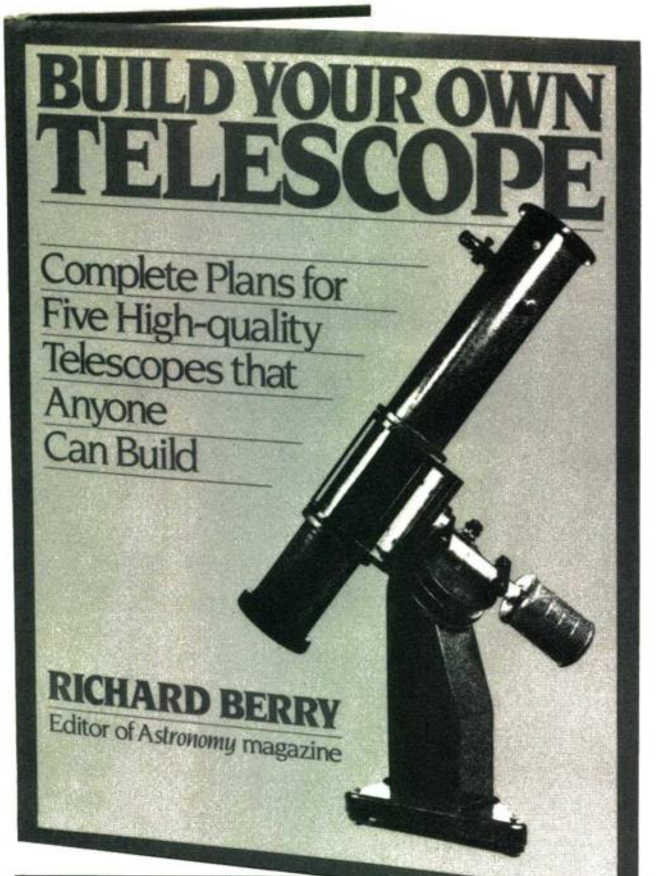

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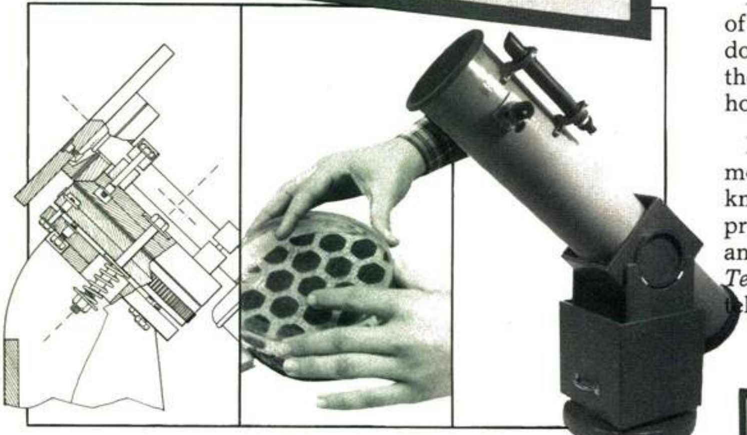

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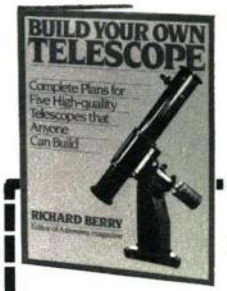

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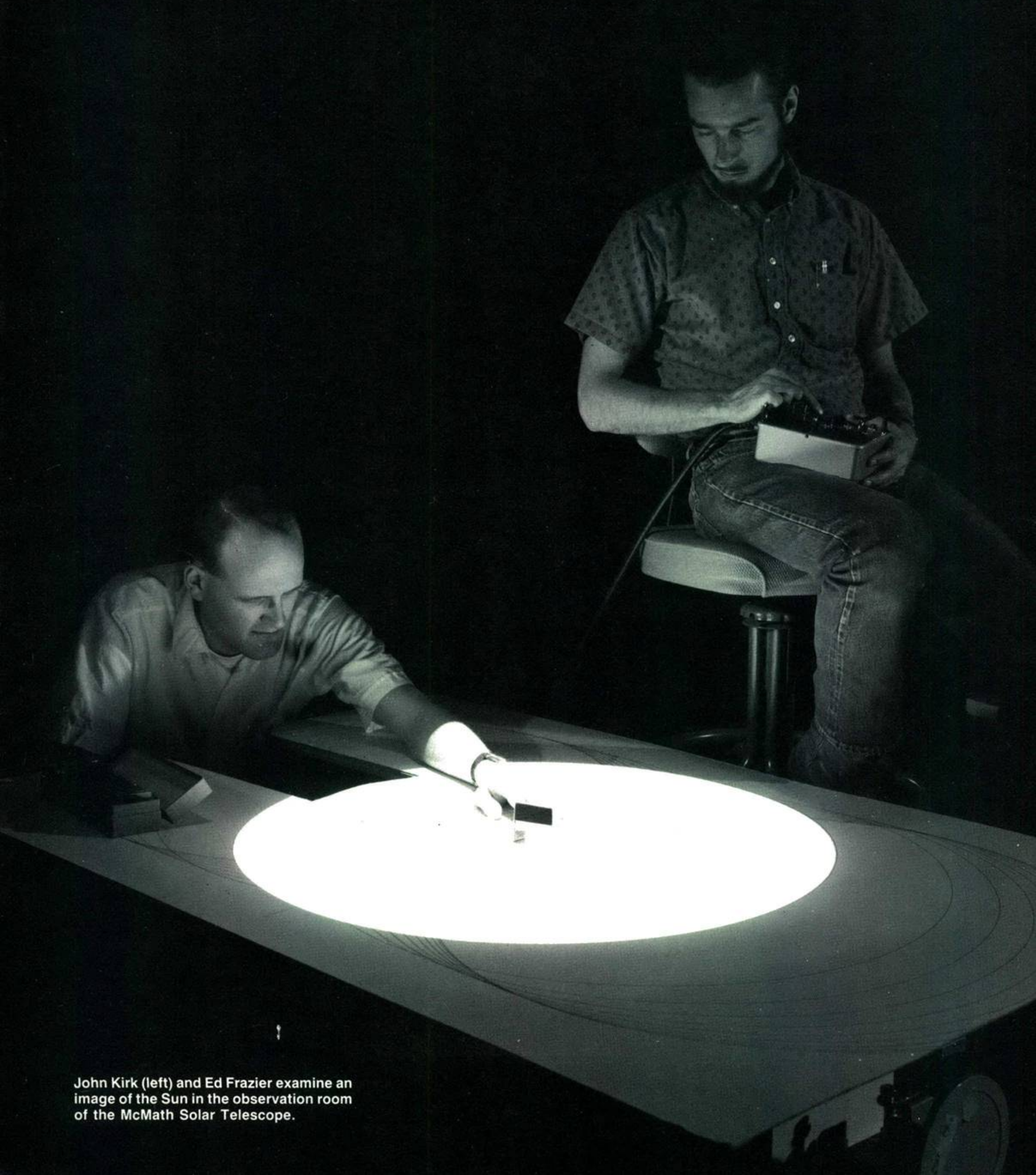


John Kirk (left) and Ed Frazier examine an image of the Sun in the observation room of the McMath Solar Telescope.

SUN

Photo by Mark Coco

BY JAMES CHARLES LOPRESTO

Like all known objects in the universe, the Sun rotates but, because it is a giant sphere of gas, it does not rotate in the manner we are familiar with. The Earth, the Moon, and the terrestrial planets all rotate as solid bodies. Every point on their surfaces takes the same length of time to spin once about their axes. On the Earth, for instance, a day is 24 hours long, independent of latitude.

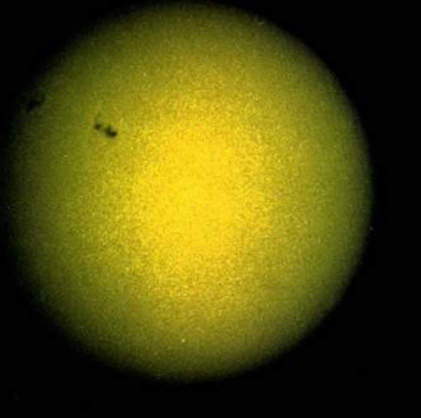
Gaseous bodies rotate much differently. In general, a location near the equator completes a rotation in less time than one at a higher latitude. This phenomenon is known as differential rotation.

Simply knowing that the Sun rotates differentially tells us very little about the Sun itself. But by thoroughly examining all aspects of solar rotation, astronomers can learn a great deal about the workings of the Sun.

The first indication that the Sun rotates came in 1610 when Galileo trained his telescope on the Sun. He was able to observe the motion of sunspots by projecting the solar image formed by his telescope onto a flat, white surface, a technique similar to that used today by many professional and amateur astronomers. By watching the daily progress of these spots across the solar disk he determined that the Sun rotates with a period of about one month.

In 1611, unaware of Galileo's work, the German astronomer Christoph Scheiner observed that sunspots near the solar equator travel around the Sun in less time than sunspots located closer to the poles. He may have been the first person to observe the differential rotation of the Sun.

Between 1853 and 1861 English astronomer Richard Carrington undertook a systematic series of observations of sunspots. From these he deduced an empirical formula describing their rotations at different latitudes. His formula gave an equatorial rotation period of between 25 and 26 days, while sunspots at



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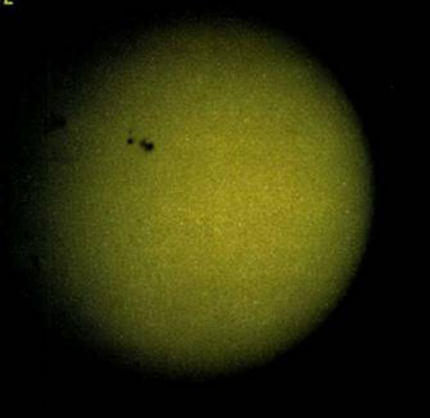

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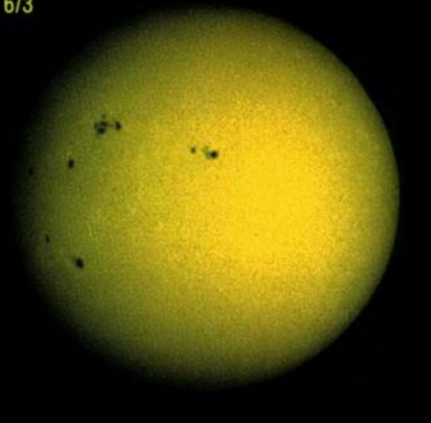

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mid-latitudes took over 2 days longer.

From this rotation period and the known size of the Sun, the rotational velocity at the Sun's equator can be determined. Simply divide the distance an equatorial sunspot travels in one rotation, which is the solar circumference of 4.37 million kilometers, by the rotational period of approximately 25 days, or 2.2 million seconds. The result is an equatorial rotational velocity of about 2 kilometers per second (km/sec).

Observing Methods

Sunspots and other visible features on a solar image are aspects of solar activity referred to as "tracers" by solar astronomers. Tracers are still used today in solar rotation studies despite three major shortcomings, all due to the nature of solar activity and the solar cycle. (The solar cycle is the approximately 11-year period in which solar activity fluctuates from minimum to maximum and back again.)

Solar activity consists of phenomena that are generally short-lived. Tracer lifetimes are often much less than one month, and in most instances are only a few days or hours. Since they rarely last for a complete rotation, astronomers must apply statistical procedures to the observations of many tracers over the course of many solar rotations. Such observations take years to complete and are difficult to interpret. If the Sun's rate of rotation should change in a short period of time, the statistical procedures used would average out these variations and make them virtually impossible to detect.

Another disadvantage is that most tracers do not occur at high solar latitudes. This restricts their use to determining rotation rates at relatively low latitudes. Finally, solar rotation rates frequently cannot be determined near the minimum of the solar cycle because tracers are often virtually nonexistent.

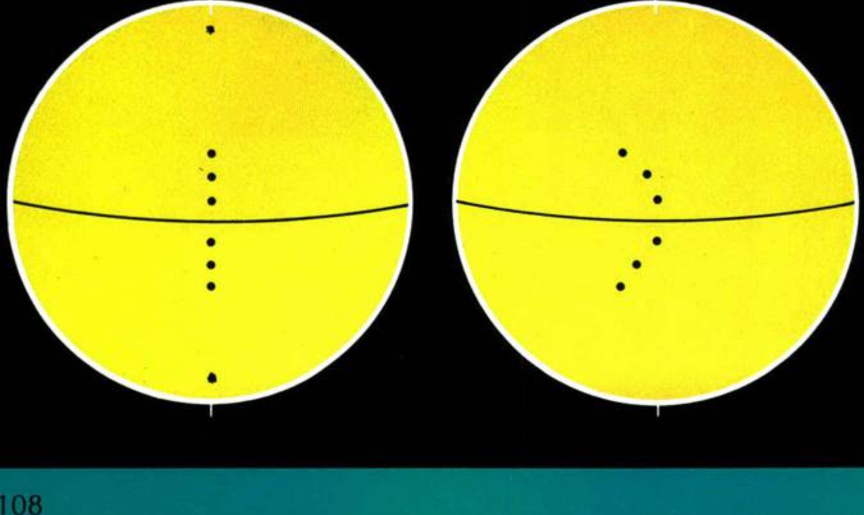
Spectroscopic observations avoid these problems and have allowed astronomers to discover both short- and long-term variations in the solar rotation rate. In the short-term these observations provide evidence that the Sun's rotation rate often varies on time scales as short as one day. Observations over the past twenty years indicate a gradual increase in the average equatorial speed of solar rotation.

Astronomers use a spectrograph to separate the light from a celestial body into its constituent colors. The optical component of the spectrograph that does this dispersion is a grating or prism. As the light passes through, it is spread into a rectangular, rainbow-colored spectrum.

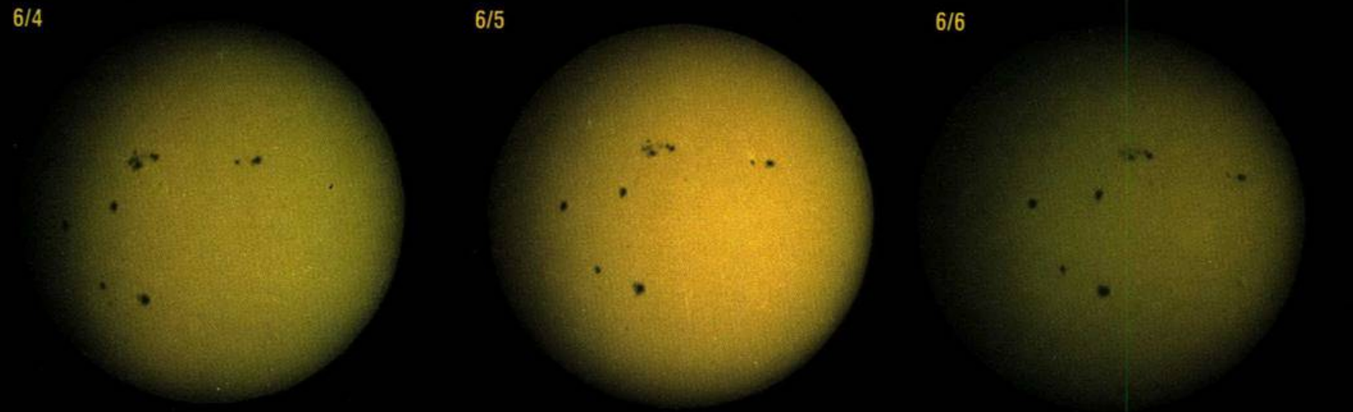
Along this spectrum the wavelength of light increases as the colors change from violet to red. Atoms within the outer layers of the source of light, however, may absorb light of a specific wavelength or scatter it in a different direction, resulting in absorption lines. These lines serve as precise wavelength markers in the spectrum.

When the light source moves toward or away from an observer on Earth, the spectrum with its absorption lines shifts. This shift is explained by the Doppler effect, which is the tool used to extract rotational information from a solar spectrum. If the motion is toward the observer, the shift is toward the blue end of the spectrum; if the motion is away, a redshift results. The amount of the shift is proportional to the speed of the source. That is, the shift in wavelength divided by the wavelength the line would have if no motion was present, equals the relative speed between the source and observer divided by the speed of light. Thus the observed spectral shift can be used to calculate

Differential Solar Rotation



The Sun rotates with a period that varies with latitude. In the highly unlikely situation shown at left, tracers at 10°, 20°, 30°, and 70° north and south all lie on the central meridian. At right is their position approximately 27 days later, when the sunspots at 10° have completed one rotation. The spots at 20° take half a day longer to rotate, and those at 30° a day longer than that. The tracers at 70° have not even reappeared yet; they take a full 10 days longer to rotate.



Solar rotation is obvious to anyone who observes the motion of sunspots over several days. Notice how the shape and structure of sunspots change as they make their way slowly across the solar disk. This sequence was taken by Lance Allred in 1979 during the last solar maximum.

the object's radial velocity — its motion along our line of sight.

Employing the Doppler Method

The German astronomer Hermann Vogel pioneered the application of the Doppler principle to astronomy by measuring the equatorial rotational velocity of the Sun. He carefully placed each of the two points where the Sun's equator meets the solar limb at the slit of a spectrograph. The dark absorption lines that he observed at each position were slightly displaced relative to those at the other limb. He reasoned that one limb was moving toward the observer and causing a blueshift, while the other was moving away and causing a redshift.

Vogel found the relative displacement of the yellow absorption line produced by sodium to be 0.078 Angstroms. (Scientists commonly use Angstroms as a unit for very small distances; 1 Angstrom equals 1 ten-billionth of a meter.) Since the wavelength of the yellow sodium line is about 5893 Angstroms when no motion is present, Vogel's observed shift represents only a 0.0013 percent change in wavelength of the unshifted line. This translates into a relative speed of the east limb with respect to the west limb of 0.0013 percent the velocity of light (300,000 km/sec), or about 4 km/sec. Thus the velocity at the Sun's equator is about 2 km/sec, the same as the result obtained by tracer methods.

The Doppler method has some important advantages over the tracer method. Observations can be obtained from all parts of the solar disk, regardless of whether tracers are visible or not. Also, the Doppler method permits extensive study of solar rotation independent of tracer methods.

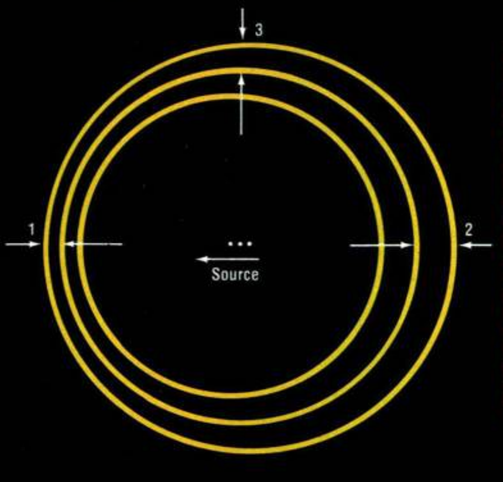
Measuring the radial velocity of an astronomical body requires the comparison of the wavelengths in its spectrum to the wavelengths produced by a laboratory light source. Usually the laboratory spectrum is an emission-line spectrum consisting of bright lines that represent the atomic composition of the light source.

In modern solar observations astronomers produce photoelectric images of the laboratory emission spectrum and the solar absorption spectrum. With this method tiny portions of the spectrum of both the laboratory source and the Sun are displayed as photoelectric tracings. The height of the tracing represents the amount of light at a given wavelength, and the horizontal direction measures wavelength. Absorption lines have characteristic profiles that appear as dips in the continuum light level. Emission lines appear as narrow spikes rising above the continuum.

Since the shifts in the Sun's spectrum are small, many measurements are necessary to obtain a reliable result, and this demands that data be acquired as rapidly as possible. Computers are generally used for both rapid acquisition of data and storage of the large amounts of data taken. After making the observations, computers are used again to measure the Doppler shift and calculate the radial velocity of the region under investigation.

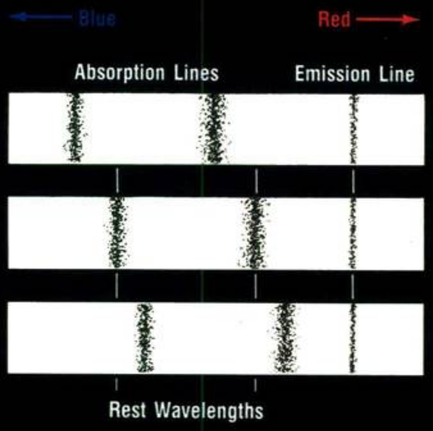
Spectroscopic methods also have a hidden bonus — they are capable of measuring the rotation rate at a variety of different depths in the solar atmosphere. The strength of a given absorption

The Doppler Effect



Light received from a moving source has a Doppler-shifted wavelength that depends on the source's motion relative to the observer.
Left: Viewed from the left, where the source is approaching, the emitted waves are shifted to shorter wavelengths (1), while to the right, where the source is receding, the light has a longer wavelength (2). When the source has no radial motion, no Doppler shift occurs (3).
Right: The rotating Sun also produces a Doppler shift. The sketches represent a spectrum of the approaching limb (top), the center of the solar disk (middle), and the receding limb (bottom).

Doppler-Shifted Spectral Lines



line (the magnitude of its dip below the continuum) indicates the atmospheric level where light of that wavelength originates. Absorption lines of greater strength form higher in the atmosphere. Such studies of solar rotation have reached the unexpected conclusion that lower lying strata seem to rotate more slowly than higher layers.

Adding to the complexity of these results are comparisons between rotations determined with the Doppler method and those gotten from tracer methods. Tracers tend to give a higher equatorial rotation rate than do the corresponding Doppler studies: 25 compared to 26 days, respectively, for one rotation at the equator. Why the measured speed of rotation should depend on the technique used to make the measurement is a matter of debate among solar astronomers. One possibility is that the techniques measure the rotation of different layers. In any case, further observations are needed to settle this issue.

Current Observations

Using the powerful spectrographs at the McMath Solar Telescope on Kitt Peak, Dr. A. Keith Pierce of Kitt Peak and I undertook an extensive observing program. Our aim was to establish if rotation rate increases with height in the solar atmosphere.

We began by taking Doppler observations near the north pole of the Sun and worked our way completely around the solar disk at intervals of approximately 5°. Each measurement was made close to the limb of the Sun. This procedure insured that the Doppler observations sampled a wide range of latitudes.

Each observation consisted of around thirty or forty photoelectric tracings of the spectral region containing both the absorption line being studied and its corresponding emission standard. (We have used about twenty-five different absorption lines in our studies.) All the tracings were then superimposed and added together by computer.

We began by making observations at 10° intervals, and at each angle we would then observe the opposite limb. After completing one circuit around the Sun, we made another circuit at 10° intervals at the intermediate angles. Each individual observation required about five minutes and one complete circuit took four or more hours of observing time.

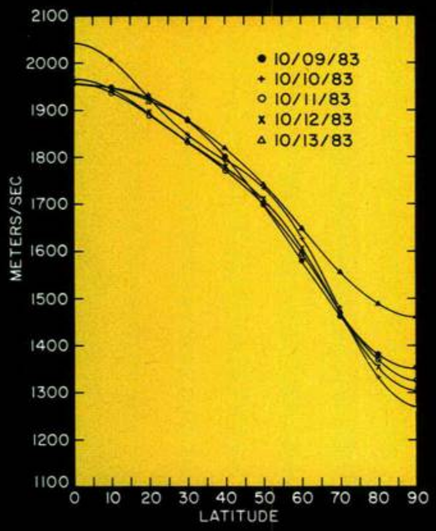
The results are displayed in the diagram at right. Near the north pole the Doppler velocity is 600 to 700 meters per second (m/sec) away from Earth. As we make our way toward the equator rotating toward Earth, the velocity decreases through zero until it reaches about 1,300 m/sec of approach at the equator. As we continue around the solar limb, the rotational velocity passes through zero again and reaches 600 to 700 m/sec of recession at the south pole. The velocity continues increasing, reaching a maximum of about 2,700 m/sec at the opposite equator before returning to the initial value.

At first glance there seems to be something terribly wrong: the poles, which should not show any effects of rotation, are redshifted by some 600 to 700 m/sec. In fact, the entire curve is redshifted by this same amount. If interpreted at face value, this implies that the entire Sun is moving away from Earth at a speed of 600 to 700 m/sec!

This portion of the redshift actually has nothing to do with radial velocity, but is instead a gravitational redshift. It occurs because light leaving the Sun must work to escape the Sun's gravitational field. This work causes a loss of energy that manifests itself as a shift to longer wavelengths. According to Einstein's theory of general relativity, the wavelength shift should be about 2 parts per million, which is equivalent to a 636 m/sec pseudo-Doppler shift.

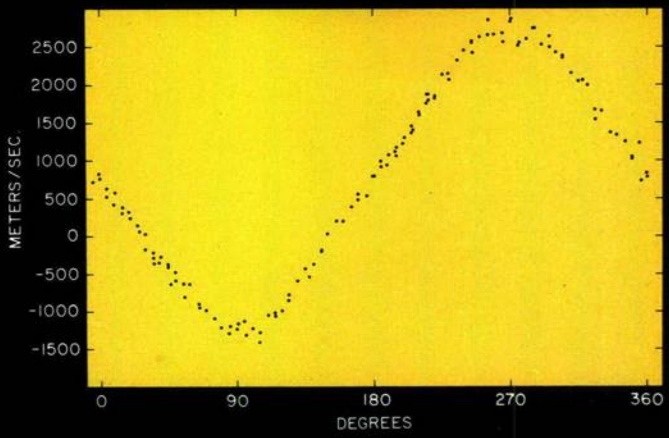
Once this gravitational redshift is subtracted from the data, we can plot a solar rotation curve. This is just a graphic representation of the way that rotational velocity changes with solar latitude. Several rotational curves are shown in the diagram on this page. The main characteristics evident in these curves show that the rotational velocity at the equator is approximately 2,000 m/sec either toward or away from Earth. (The east limb approaches Earth and the west limb recedes.) This value falls to much lower velocities at very high latitudes near either pole.

Solar Rotation Curves



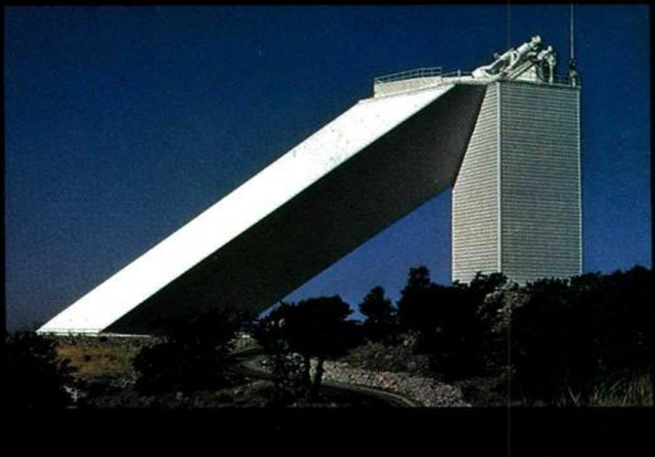
The rotational velocity of the Sun decreases steadily as latitude increases from the equator to both poles. Here are solar rotation curves for five consecutive days, showing the general trend of short-term stability between 30° and 70° latitude and more substantial variation outside that range.

Doppler Velocity of the Solar Surface



From measurements of the Doppler shift of solar spectral lines, we can see how the Sun's apparent radial velocity varies with position around the solar limb. The curve starts at the north pole (0°) and moves eastward. The maximum velocity of approach is reached at the east limb of the Sun (90°) and the maximum recessional velocity occurs at the west limb (270°). The entire curve has an apparent excess recessional velocity of 600 to 700 m/sec due to the gravitational redshift.

The McMath Solar Telescope on Kitt Peak is one of the leading observatories providing information on the Sun. Photo by Jay Pasachoff.



(It does not fall to zero because the instrumentation cannot resolve the exact pole, but instead lets in light from surrounding regions.)

Our observations have revealed or expanded on several significant points.

- Comparison of our observations with previous studies show that the average rotational velocity has been slowly increasing over the past twenty years.
- At latitudes between 30° and 70° the rotation rate seems quite stable over short periods of time. Observations from many different days give very similar results.
- The latitude region between 0° and 30° shows variations in rotation rate in periods as short as one day.
- We have evidence supporting the notion that rotational velocity increases with height in the solar atmosphere, although we haven't been able to reach any conclusions about the causes of the effect.
- On a few of the curves the regions at very high latitudes show the possible existence of a vortex or whirlpool-like motion. This is indicated by the upward turn of the curves, which implies that the rotational velocity is increasing. This interpretation is highly uncertain, however, since obtaining data near the poles has a large, built-in error that makes the velocities uncertain.

Trying to measure the redshift at high latitudes is quite difficult. There are many complex motions taking place in the solar atmosphere, motions both toward and away from Earth-bound observers. Each radial velocity measurement is the result of the combined shift from all these various motions and the gravitational redshift.

The most obvious motion contributing to the Doppler shift is solar rotation and its observed variations. Long-term rotational variations have been observed by Robert Howard and others working at the Mount Wilson Observatory. Some of their observations show that certain small bands of solar latitude rotate faster than neighboring bands. These bands seem to start at high solar latitudes near the beginning of a solar cycle and migrate toward the equator as the solar cycle progresses toward maximum.

Rising and falling columns of gas give rise to their own Doppler shifts. These motions result from convection in the solar atmosphere, which causes fountains of hot gas to rise. The gas eventually cools and then falls back through the photosphere.

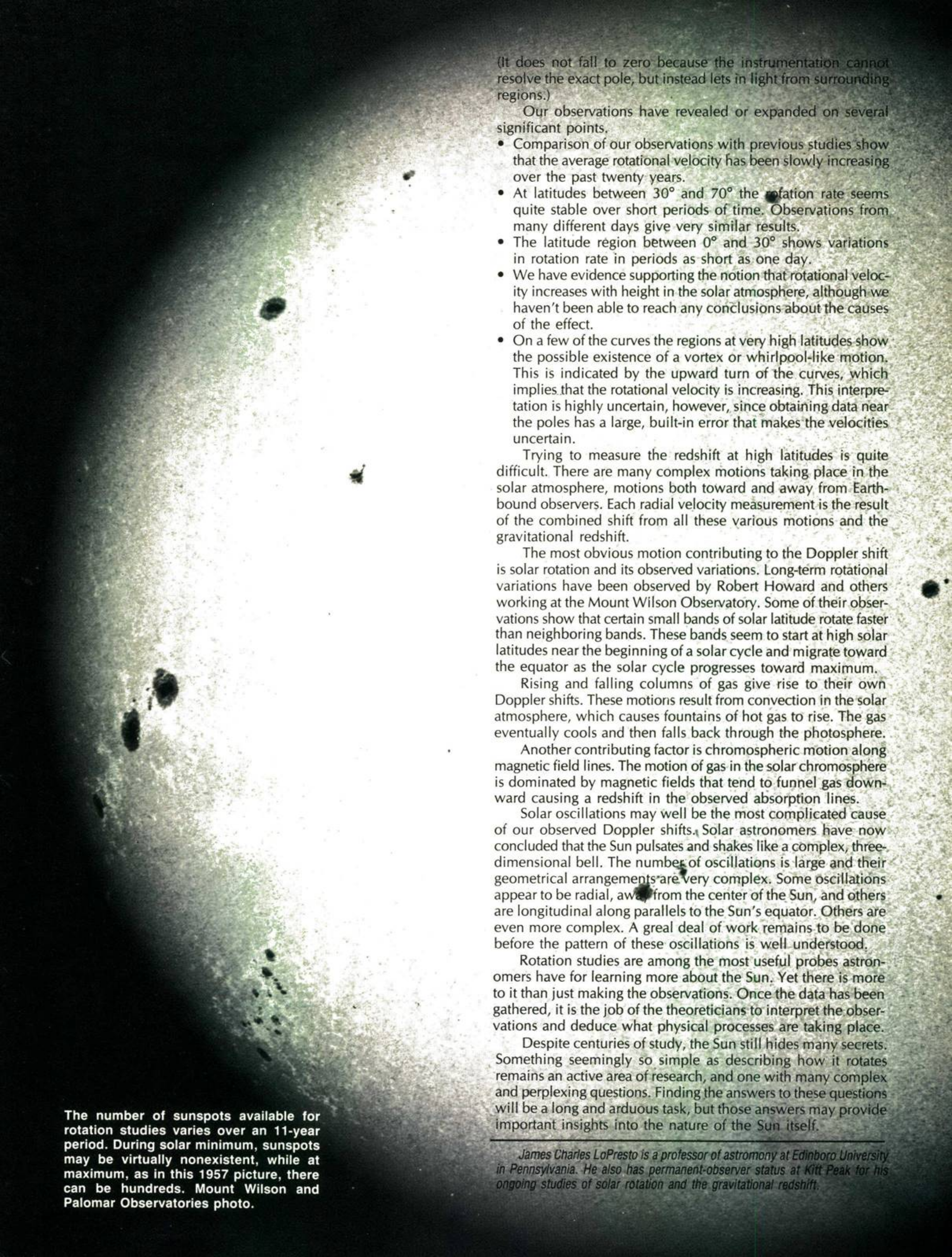
Another contributing factor is chromospheric motion along magnetic field lines. The motion of gas in the solar chromosphere is dominated by magnetic fields that tend to funnel gas downward causing a redshift in the observed absorption lines.

Solar oscillations may well be the most complicated cause of our observed Doppler shifts. Solar astronomers have now concluded that the Sun pulsates and shakes like a complex, three-dimensional bell. The number of oscillations is large and their geometrical arrangements are very complex. Some oscillations appear to be radial, away from the center of the Sun, and others are longitudinal along parallels to the Sun's equator. Others are even more complex. A greal deal of work remains to be done before the pattern of these oscillations is well understood.

Rotation studies are among the most useful probes astronomers have for learning more about the Sun. Yet there is more to it than just making the observations. Once the data has been gathered, it is the job of the theoreticians to interpret the observations and deduce what physical processes are taking place.

Despite centuries of study, the Sun still hides many secrets. Something seemingly so simple as describing how it rotates remains an active area of research, and one with many complex and perplexing questions. Finding the answers to these questions will be a long and arduous task, but those answers may provide important insights into the nature of the Sun itself.

James Charles LoPresto is a professor of astromony at Edinboro University in Pennsylvania. He also has permanent-observer status at Kitt Peak for his ongoing studies of solar rotation and the gravitational redshift.



The number of sunspots available for rotation studies varies over an 11-year period. During solar minimum, sunspots may be virtually nonexistent, while at maximum, as in this 1957 picture, there can be hundreds. Mount Wilson and Palomar Observatories photo.

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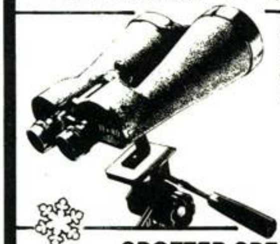

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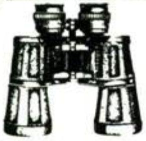

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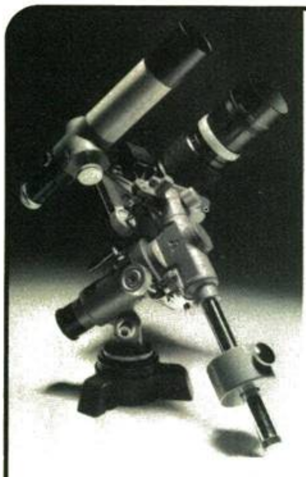

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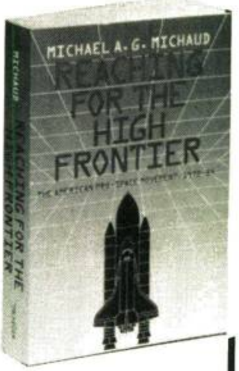

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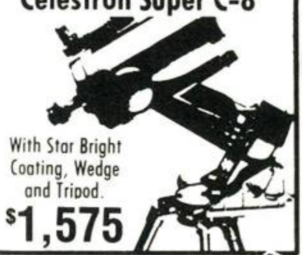

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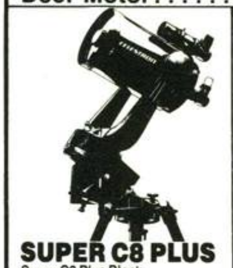

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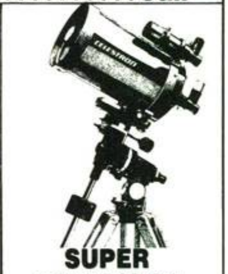

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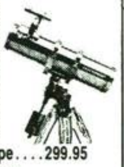

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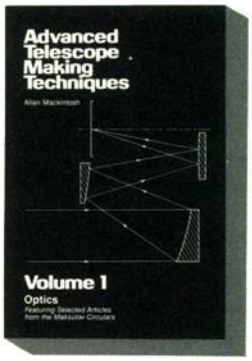
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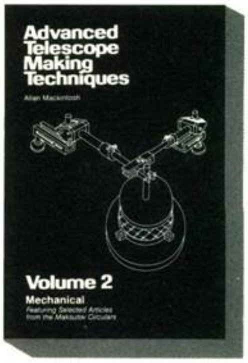
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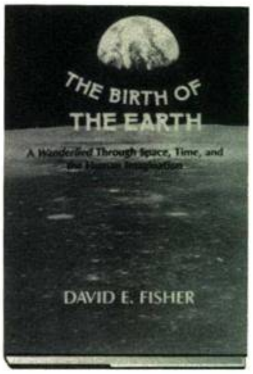
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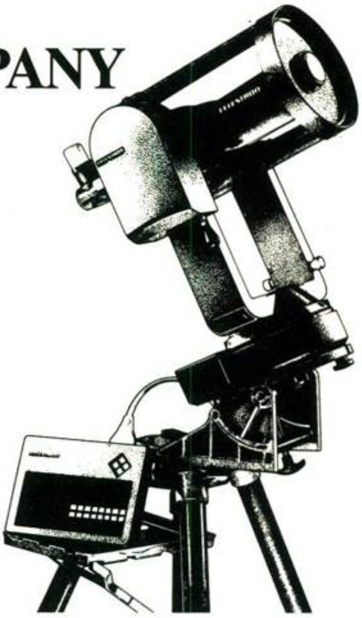

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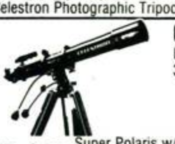

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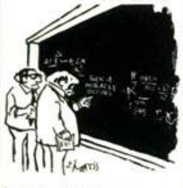

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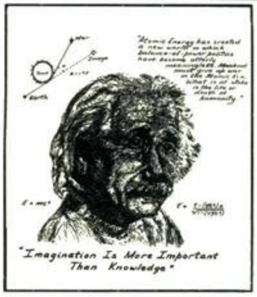
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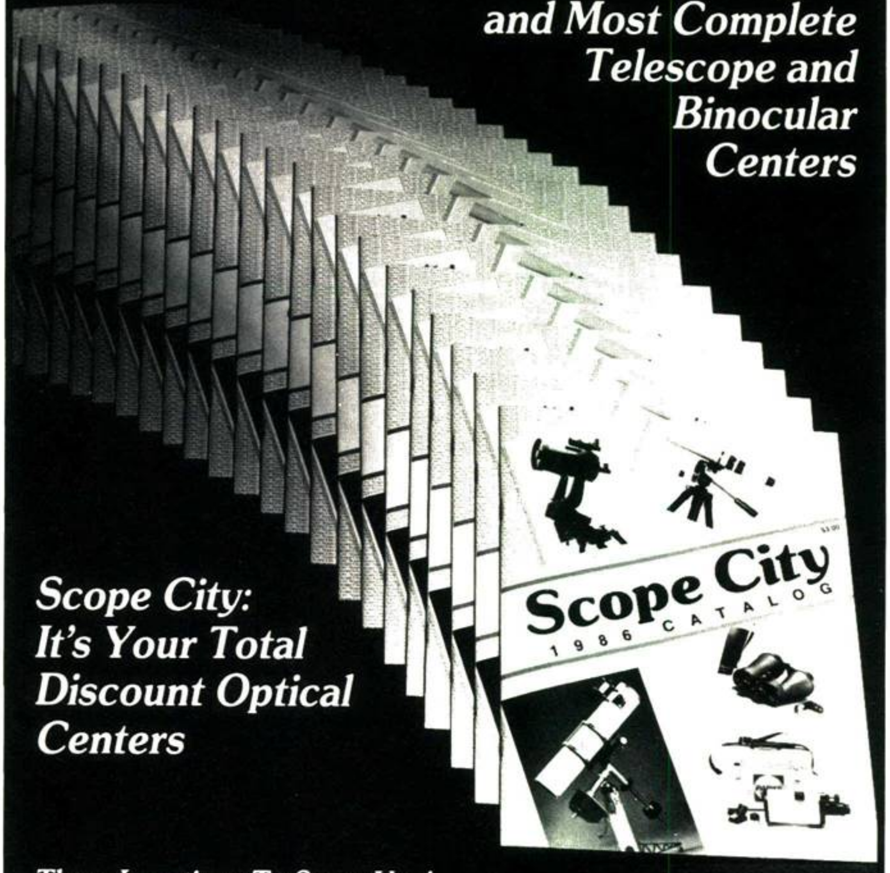

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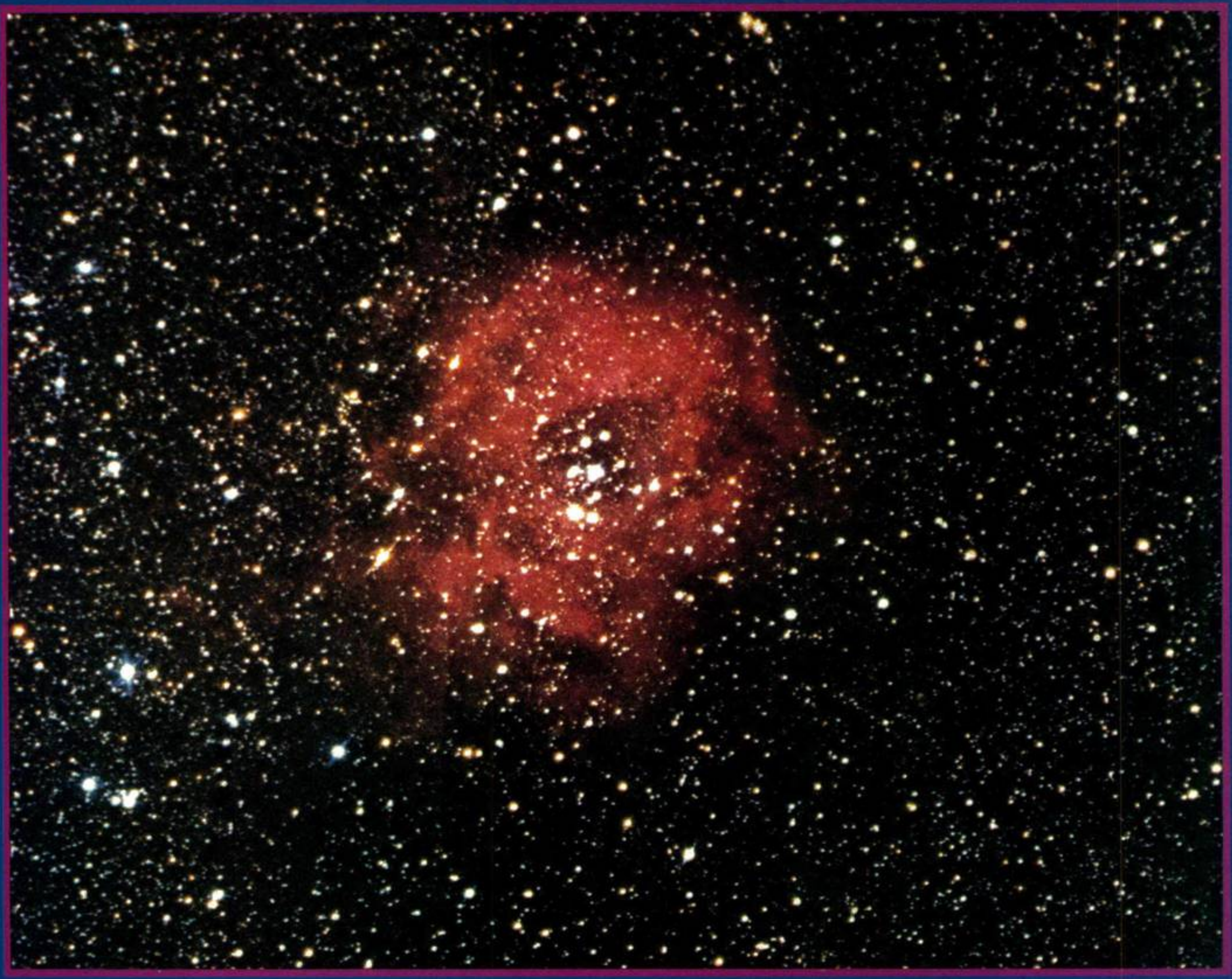
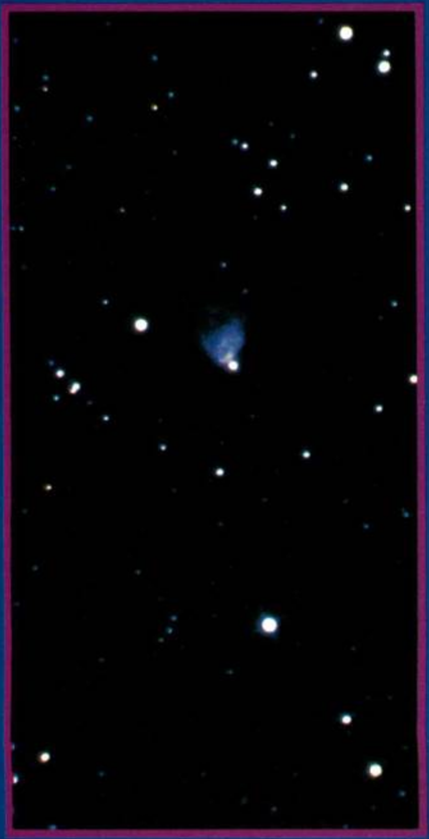
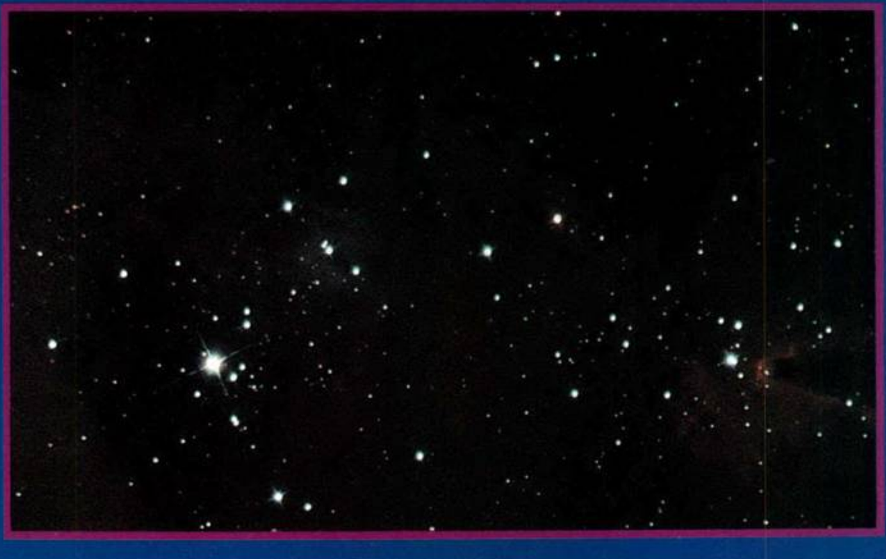






Top: The Rosette Nebula in Monoceros is one of the largest emission nebulae in the sky. The brightest sections of its faint, wreath-shaped outline may be glimpsed in a 6-inch telescope at low power. Photo by Mace Hooley.

Above: The Cone Nebula is a 5′ by 3′ cloud of dust particles backlit by a piece of the emission complex called NGC-2264. It is a difficult object to view because of the low surface brightness of the NGC-2264 nebulosity. *Photo* by Jack Newton.

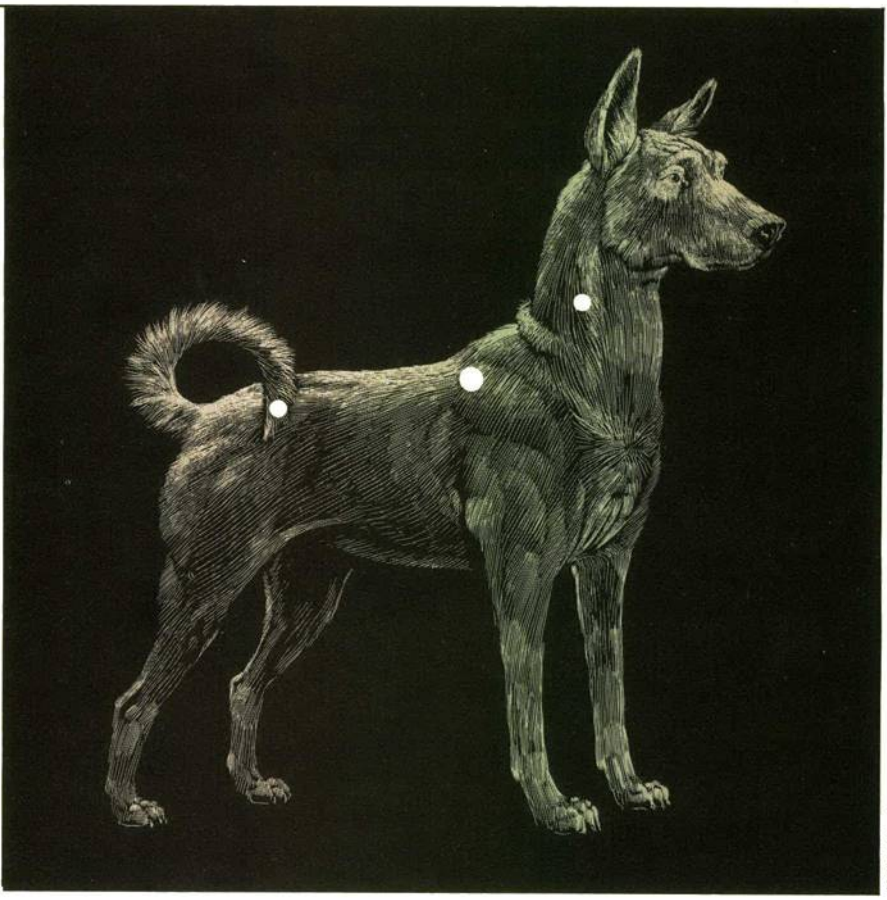
Left: Variable in size and luminosity along with the irregular variable R Monocerotis, the tiny triangular nebula NGC-2261 is visible, even at its ''minimum,'' in small backyard scopes. Photo by John P. Gleason.

Monoceros

Mon
Monocerotis

Canis Minor

CMi
Canis Minoris



Keith Ward

Lying amidst the winter Milky Way **Monoceros** the Unicorn and **Canis Minor** the Little Dog each contain bright objects for backyard deep-sky observers. Monoceros, nearly centered on the galactic equator, is rich in open clusters and complex regions of bright and dark nebulosity. Canis Minor, covering a mere 183 square degrees (as opposed to Monoceros' 482 square degrees) and lying a little farther from the galactic equator, is devoid of bright nebulous objects. But it contains a bright and unusual star, a joy to observe for devotees of optical double stars.

The most unusual star cluster in Monoceros is **NGC-2244**, a grouping of some 100 stars found 2.5° east of the bright double star Epsilon (ε) Monocerotis. Since it has a total magnitude of 4.8, you can see NGC-2244 as a fuzzy "star" with your unaided eye under a very dark sky, if you know exactly where to look. Finder scopes show this cluster as a sprinkling of tiny stars some 24′ in diameter superimposed on a milky nebulous glow. NGC-2244's brightest star shines at magnitude 5.8 and is a type O5 bluish white giant. Nearly as bright is 12 Monocerotis, a yellowish K0 giant. Can you spot its distinct color in your scope? A 6-inch scope at low power shows dozens of stars in the cluster, the most prominent being the cluster's six brightest stars, arranged in pairs that make up a rectangle some 20′ long. Scattered inside this rectangle, and to a lesser degree outside of it, lie the remaining ninety-plus stars.

If you view NGC-2244 with a larger telescope under a dark sky, you may be in for a surprise. Surrounding the cluster is a faint emission nebula that is catalogued as NGC-2237, NGC-2238, NGC-2239, and NGC-2246, but popularly known as the **Rosette Nebula**. This wreath-shaped cloud of hydrogen gas is the material from which NGC-2244's constituent stars formed. The cluster is exceedingly young, probably not more than 3 million years old, and as the cluster continues to grow the Rosette's gas will continue to either gravitationally contract into the cluster or be driven off by stellar winds from the already-formed suns. In several tens of millions of years — a blink on the astronomical time scale — the Rosette Nebula will disappear.

The Rosette Nebula and its attendant cluster lie at a distance of about 1.7 kiloparsecs, giving the 80′ by 60′ wreath an actual diameter of some 40 parsecs and making the Rosette one of the largest and most massive nebulae known. The star cluster itself has a physical diameter of about 12 parsecs.

The Rosette Nebula is a difficult, low-contrast object to observe. With a 10- or 12-inch telescope at low power, try spotting it on a night of good transparency when the Moon is out of the sky. You may see it as a large, circular shell of faint gray nebulosity about 1° across. You'll probably see a dark central "hole" — although some observers claim that the nebula appears to be uniformly lit in small telescopes — and dimly glowing, knotty patches of light along the brightest part of the nebulosity.

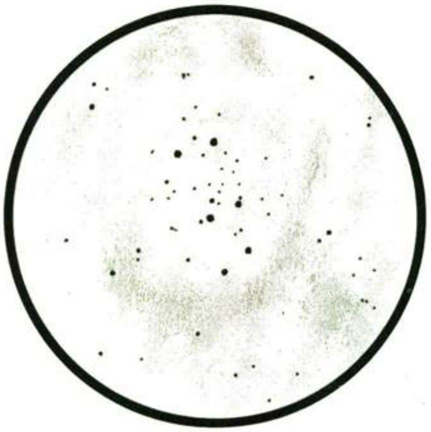
Using high power, scan along the brightest parts of the nebula and you may well spot tiny, dark patches that appear generally circular, silhouetted against the bright nebulosity. These are Bok globules, small dark nebulae physically involved with the Rosette (and other nebulae) and thought to be regions where dust is collapsing to form stars.

For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.

Five degrees north-northeast of the Rosette Nebula is a giant complex of bright and dark nebulae, the brightest part of which is designated **NGC-2264**. NGC-2264 is a magnitude 3.9 open cluster that lies much closer than NGC-2244 — some 750 parsecs — and contains only forty stars. NGC-2264's stars are arranged in a pattern that seems so familiar that the well-known amateur astronomer Leland S. Copeland dubbed NGC-2264 the "Christmas Tree Cluster." The cluster's brightest star, a 5th-magnitude O7 giant called S Monocerotis, lies at the base of the tree; nine other bright stars are nearly perfectly placed to outline the tree. Other observers simply call NGC-2264 diamond-shaped.

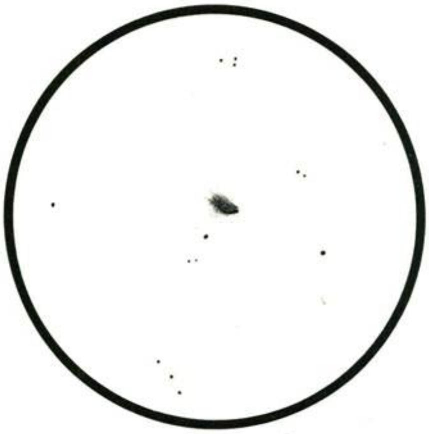
S Monocerotis is itself an object for backyard telescopes. Irregularly variable between magnitudes 4.2 and 4.6, the star has a computed absolute magnitude of −5.0, meaning that it shines with the light of 8,500 Suns, and is super-hot; it is also a visual double star with a magnitude 7.5 companion some 2.8″ away in p.a. 213°.

A great cloud of nebulosity covers the star cluster NGC-2264 and its environs, a nebula that is much fainter than the Rosette. The brightest section of this nebulosity carries the same NGC number as the



NGC-2237-9

17.5-inch
f/4.5 reflector
71x



NGC-2261

17.5-inch
f/4.5 reflector
71x

Sketches by David J. Eicher

cluster, 2264, and measures 60′ by 30′ in extent. Floating in front of the NGC-2264 nebulosity, some 40′ south of the star cluster, is one of the sky's finest examples of a contrasty, opaque dark nebula — the **Cone Nebula**. This cone-shaped dark patch is about 5′ long and 40″ to 3′ wide, and is visible as a black smear against gray nebulosity on very dark nights with the largest backyard telescopes.

Also a part of the NGC-2264 nebular complex, and lying some 2° southwest of the star cluster, is the curious reflection nebula **NGC-2261**, also called Hubble's Variable Nebula. Discovered by William Herschel in 1783, this peculiar triangular (2′ by 1′) nebula envelops the bright variable star **R Monocerotis**, and therefore varies in size and brightness along with the star.

The variability of R Mon was discovered at the Athens Observatory in 1861, but it wasn't until 1916 that Edwin P. Hubble discovered that the nebula itself varies, even to the point where photographs made several weeks apart — even amateur photos — show significant structural changes in the nebulosity.

The most intense study of NGC-2261 was done by Carl O. Lampland at Lowell Observatory, who made over 900 photographs of the object over a 30-year period. Lampland found no periodicity in the variance, but to his surprise he found that details in the nebula changed by as much as 1.0″ displacement in just four days! Evidently the changes are produced by shadows cast on the nebulosity by dark material orbiting the star R Mon.

Although reflection nebulae are notoriously faint, Hubble's Variable Nebula is unusual in that it has a very high surface brightness. This allows you to observe it using high powers on nights of very steady seeing and crisp transparency and to compile a series of drawings (or photographs) of the nebula's shape. It's quite possible to see the strange object change considerably in short periods of time. It probably lies some 750 parsecs away.

Other bright open clusters inhabit Monoceros. Of these, **M-50** (NGC-2323) is the best. It contains eighty stars in an area spanning 16′, creating a total magnitude of 5.9 — just on the limit of naked-eye visibility from a perfectly dark site. The cluster is attractive in binoculars as it contains many arcs of stars and a solitary ruddy star about 7′ south of the group's center. **NGC-2301** is a fine object for small telescopes, glowing at magnitude 6.0 and measuring 12′ across. This highly compressed group contains eighty stars of magnitudes 8.0 and fainter and is attractive even in small refractors and binoculars. The cluster **NGC-2353** is a 20′-diameter collection of thirty stars. Their combined light is equivalent to that of a magnitude 7.1 star. A favorite for those observers who know of it, **NGC-2506** is one of the richest groups of stars in its part of the sky, holding 150 stars of magnitude 10.8 and fainter in an area only 7′ across.

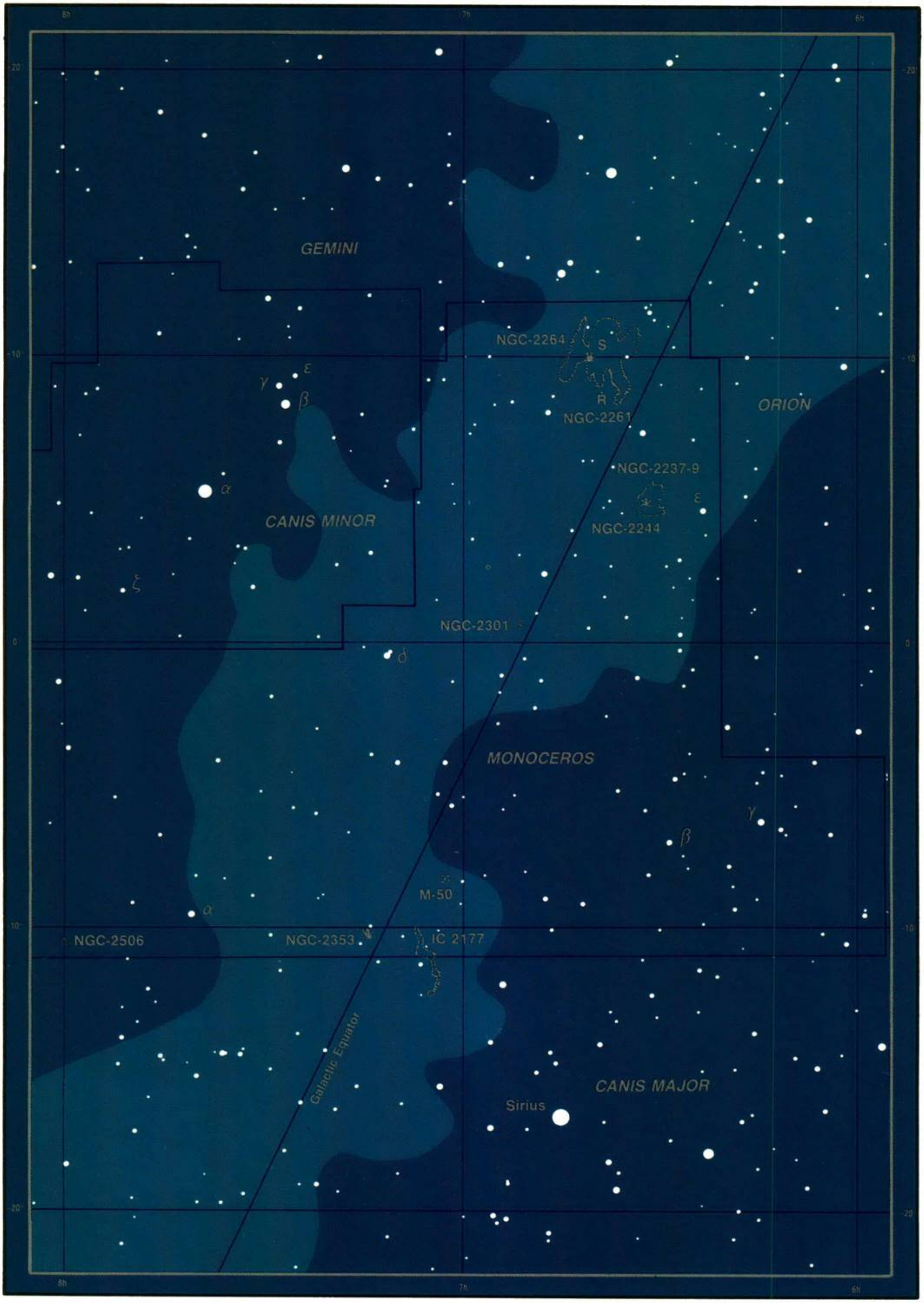
One of the prime examples of a triple star visible in small telescopes, **Beta** (*β*) **Monocerotis** should not be overlooked by even casual double-star aficionados. Lying about 11° south of the Rosette Nebula, Beta Mon contains a magnitude 4.7 primary and a 5.2 secondary separated by 7.3″ in p.a. 132°, and a magnitude 6.1 companion lying 10.0″ away in p.a. 124°. The three stars make a lovely sight surrounded by a rich, bright starfield; the only thing lacking is exotic star colors, since all three suns are brilliant white.

Canis Minor's prime attraction is the dazzling star **Procyon** (Alpha [*α*] Canis Minoris), a magnitude 0.4 luminary. It is the eighth brightest star in the sky. It is also the fifth closest of the naked eye stars, at a distance of 3.5 parsecs. Procyon is an easy optical double, with a magnitude 11.6 star 2′ away in p.a. 13°, but an impossible binary star — a physically associated magnitude 12.9 white dwarf — lies only 5″ away and is overwhelmed by the brilliance of Procyon. It is visible only in the largest telescopes.

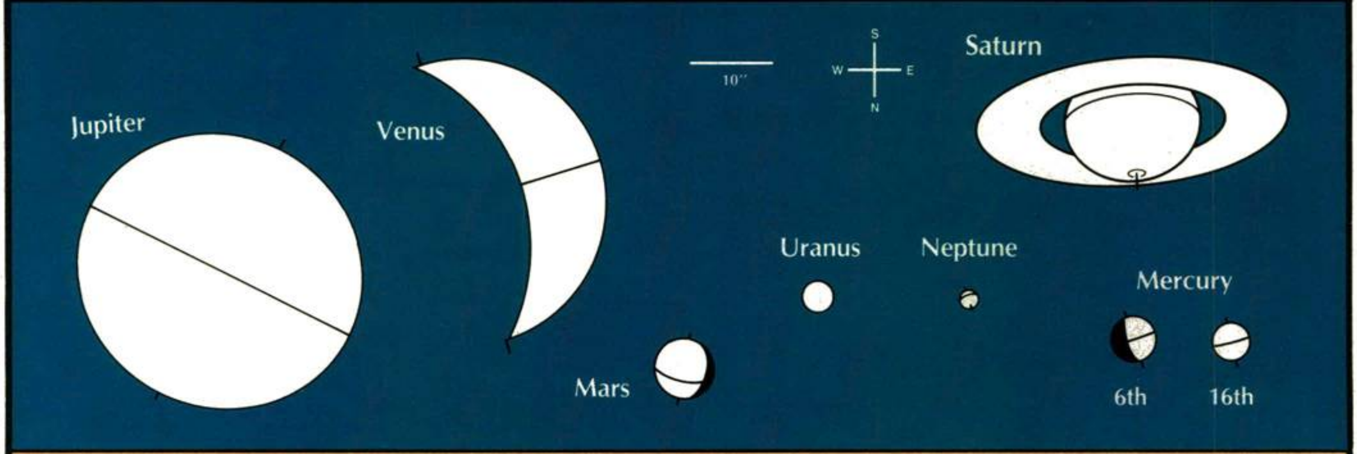
Object	M#	Type	R.A. (2000)	Dec.	Mag.	Size/Sep./Per.	N★
Beta (β)		★^{3}	6h 28.8m	− 7°02′	4.7,5.2,6.1	7.3″,10.0″	
NGC-2237-9,46		□E	6h 32.3m	+ 5°03′	—	80′x60′	
NGC-2244		⊙	6h 32.4m	+ 4°03′	4.8	24′	100
NGC-2261		□R	6h 39.2m	+ 8°44′	—	2′x1′	
S Mon		IV	6h 41.0m	+ 9°54′	4.2↔4.6	irr.	
NGC-2264		⊙□E	6h 41.1m	+ 9°53′	3.9	60′x30′	
NGC-2301		⊙	6h 51.8m	+ 0°28′	6.0	12′	80
NGC-2323	M-50	⊙	7h 03.2m	− 8°20′	5.9	16′	30
NGC-2353		⊙	7h 14.6m	−10°18′	7.1	20′	30
Procyon (α CMI)		★^{2}	7h 39.3m	+ 5°14′	0.4,12.9	5″	
NGC-2506		⊙	8h 00.2m	−10°47′	7.6	7′	150

★^{2}	*Double Star*
★^{3}	*Triple Star*
IV	*Irregular Variable*
⊙	*Open Star Cluster*
□E	*Emission Nebula*
⊙□E	*Emission Nebula with Star Cluster*
□R	*Reflection Nebula*

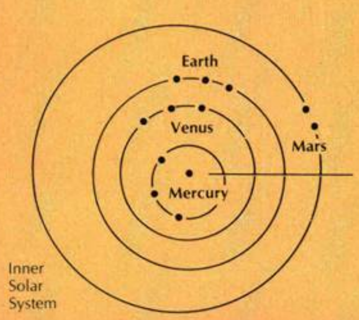
N★ = number of stars.

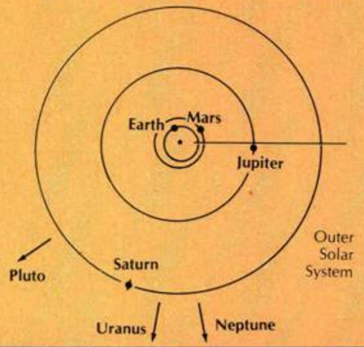

8h
7h
6h
+20
+10
0
-10
-20
GEMINI
γ
ε
β
α
CANIS MINOR
ζ
NGC-2264
S
R
NGC-2261
ORION
NGC-2237-9
ε
NGC-2244
NGC-2301
δ
MONOCEROS
γ
β
M-50
α
NGC-2506
NGC-2353
IC 2177
Galactic Equator
CANIS MAJOR
Sirius

Planetary Data December 1986


Jupiter
Venus
10″
S
W
E
N
Saturn
Uranus
Neptune
Mercury
Mars
6th
16th

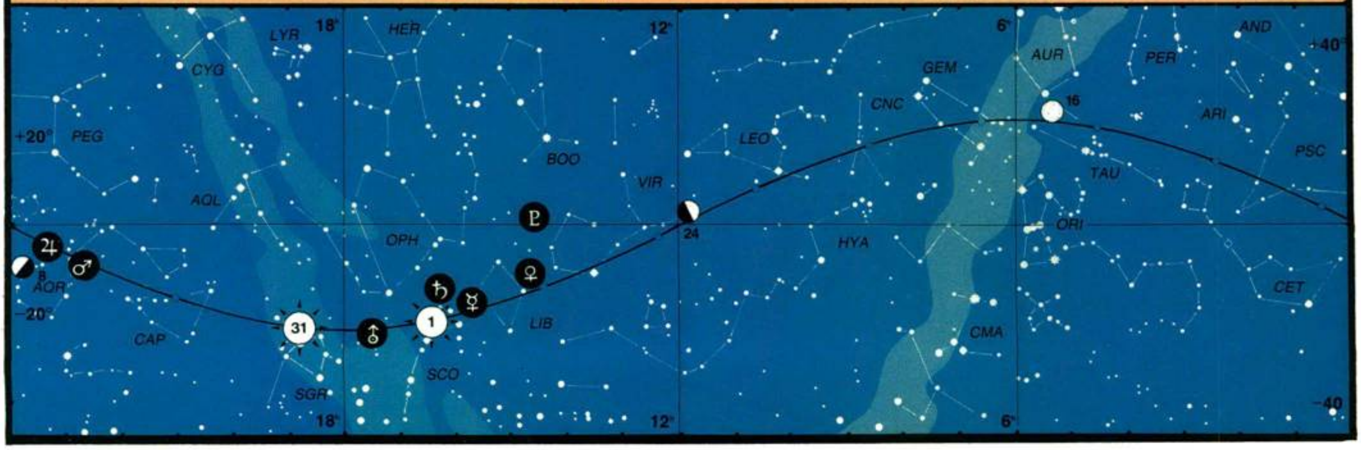
				Angular	%	Distance (AU) from:		Longitude:			
		Date	Mag.	Size	Illum.	Earth	Sun	Heliocentric	Ecliptic	R.A. (2000.0)	Dec.
Sun		1	−26.8	32.5′	—	0.986	—	—	248°29.7′	16h 27.8m	−21°45.1′
		15	−26.8	32.8′	—	0.984	—	—	262°42.7′	17h 29.0m	−23°15.1′
		31	−26.8	32.6′	—	0.983	—	—	279°00.4′	18h 40.0m	−23°07.5′
Mercury	☿	1	−0.5	6.6″	64%	1.028	0.355	154°58.9′	228°37.8′	15h 07.3m	−15°08.6′
		15	−0.5	5.2″	90%	1.289	0.430	209°32.6′	247°26.2′	16h 22.9m	−20°48.5′
		31	−0.7	4.7″	98%	1.424	0.467	255°54.1′	271°48.6′	18h 07.9m	−24°30.1′
Venus	♀	1	−4.6	47.9″	17%	0.348	0.720	83°49.7′	216°00.5′	14h 14.2m	−12°32.2′
		15	−4.7	38.2″	29%	0.437	0.719	106°28.4′	221°27.0′	14h 39.2m	−12°34.8′
		31	−4.6	30.2″	41%	0.553	0.718	132°26.6′	233°32.4′	15h 27.8m	−15°04.9′
Mars	♂	10	0.3	8.0″	86%	1.172	1.420	22°50.8′	339°40.5′	22h 46.4m	−8°52.7′
		20	0.4	7.5″	87%	1.250	1.430	28°48.8′	346°32.5′	23h 11.8m	−5°59.2′
Jupiter	♃	15	−2.4	39.4″	99%	4.997	4.965	356°30.9′	345°22.3′	23h 08.0m	−6°56.1′
Saturn	♄	15	0.4	15.1″	100%	10.983	10.014	252°31.7′	254°46.8′	16h 49.7m	−20°57.6′
Uranus	⛢	15	5.7	3.5″	100%	20.165	19.181	262°34.6′	262°45.8′	17h 28.4m	−23°21.3′
Neptune	♆	15	8.0	2.2″	100%	31.200	30.240	275°27.2′	275°15.4′	18h 22.6m	−22°19.6′
Pluto	♇	15	13.8	0.1″	100%	30.376	29.701	217°37.3′	219°05.6′	14h 47.3m	0°40.1′


Earth
Venus
Mars
Mercury
Inner
Solar
System


Earth
Mars
Jupiter
Pluto
Saturn
Uranus
Neptune
Outer
Solar
System

Moon Data

New Moon........December 1 at 16h43m
First Quarter........December 8 at 8h01m
Full Moon........December 16 at 7h04m
Last Quarter.......December 24 at 9h17m
New Moon........December 31 at 3h10m
Perigee: Dec. 2 at 10h32m.....357,737 km
Apogee: Dec. 17 at 5h06m....406,507 km
Perigee: Dec. 30 at 23h15m....356,615 km


LYR
18h
HER
12h
6h
AUR
AND
+40°
CYG
GEM
PER
CNC
16
ARI
+20°
PEG
LEO
BOO
PSC
TAU
AQL
VIR
♇
24
ORI
OPH
HYA
♃
♂
8
AQR
♀
CET
−20°
♄
☿
CAP
31
⛢
1
LIB
CMA
SCO
SGR
18h
12h
6h
−40

Two months before opposition, Jupiter was displaying a large disk and many cloud features. This ½-second exposure by Kim Zussman was made with an 11-inch SCT at f/79 using Ektachrome 200 film.

Mercury

This month Mercury finishes an apparition in the predawn sky which began in November. Forty-five minutes before sunrise on December 1, Mercury has an elevation in the southeast of about 10°, but by the 22nd or 23rd it is too low to be seen. Since greatest elongation from the Sun was on November 30, your medium-power eyepiece will show a featureless disk changing from half-lit (on the 1st) to distinctly gibbous by the time it vanishes into the sunrise. This is the best opportunity for viewing Mercury this year — don't let it pass you by.

Venus

Venus rises about three hours before the Sun this month, but even when morning twilight is well advanced the "Morning Star" will be only about 25° high in the southeast. Nevertheless, you'll have no trouble identifying it since nothing else (apart from the Sun and Moon) is so bright. On December 11, Venus is at magnitude −4.6, its brightest for this morning appearance.

Between now and January 15 (the date of greatest elongation), use your telescope and low- to moderate-power eyepieces to observe how Venus' phase goes from crescent toward half-lit. Keep watching as twilight strengthens because the brightening sky lessens the glare from the white disk of Venus.

Earth

On December 22 at 4h02m UT, the Sun, in its apparent annual motion, will be at its greatest angular distance south of the celestial equator. This moment is the December solstice, which marks the beginning of winter in the Northern Hemisphere.

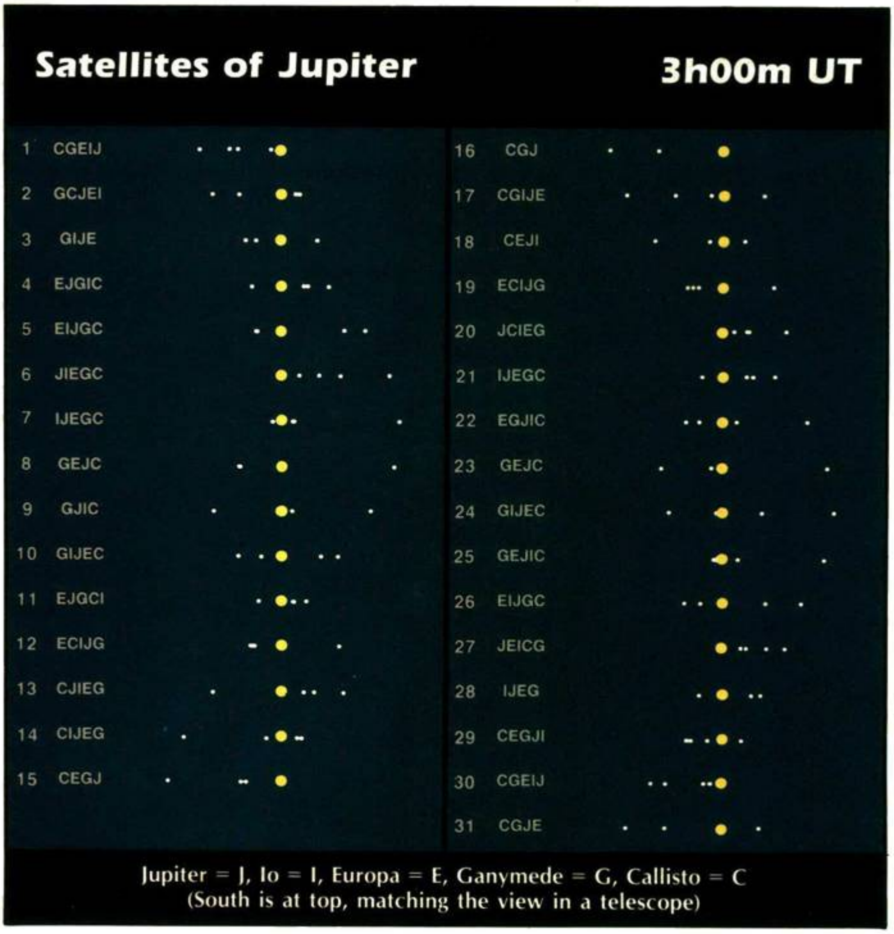
Mars

Although it is steadily climbing higher

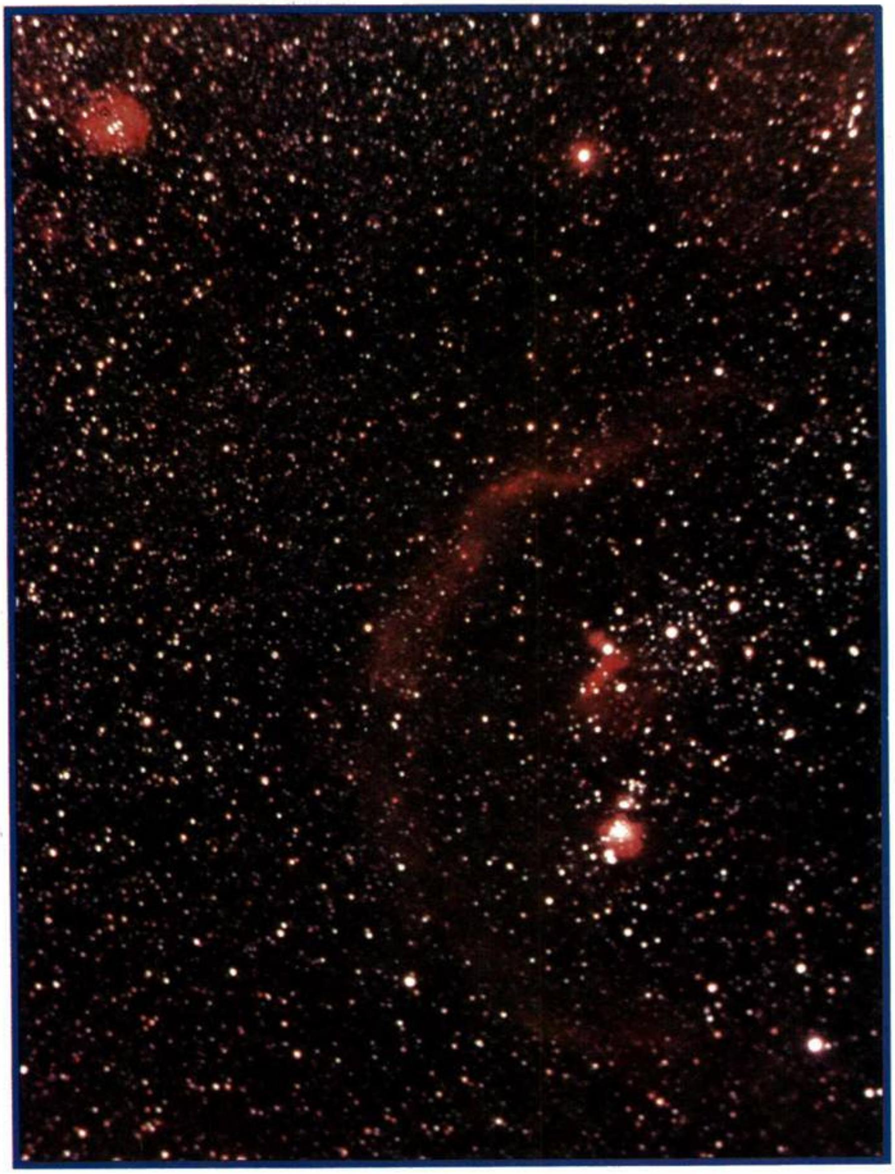
Universal Time

Astronomers the world over use an unambiguous system of time reckoning — Universal Time (UT) — based on a 24-hour clock. Times in "The Backyard Astronomer" are UT unless otherwise noted. To convert UT into your local standard time, subtract the following number of hours for each time zone: EST, 5; CST, 6; MST, 7; PST, 8; Alaska, 9; Hawaii, 10.

For example, if an event is to happen at 3h00m UT on December 2, then EST for the event is 10 p.m., December 1. Likewise, 13h00m UT on January 5 becomes 5 a.m. PST January 5.


Satellites of Jupiter
3h00m UT
1 CGEIJ
2 GCJEI
3 GIJE
4 EJGIC
5 EIJGC
6 JIEGC
7 IJEGC
8 GEJC
9 GJIC
10 GIJEC
11 EJGCI
12 ECIJG
13 CJIEG
14 CIJEG
15 CEGJ
16 CGJ
17 CGIJE
18 CEJI
19 ECIJG
20 JCIEG
21 IJEGC
22 EGJIC
23 GEJC
24 GIJEC
25 GEJIC
26 EIJGC
27 JEICG
28 IJEG
29 CEGJI
30 CGEIJ
31 CGJE

Jupiter = J, Io = I, Europa = E, Ganymede = G, Callisto = C
(South is at top, matching the view in a telescope)



Left: The field of this photo contains a number of fine nebulous regions in and around Orion. The brightest patch near the center is M-42, with the dark Horsehead Nebula just above it. The long arc of nebulosity is "Barnard's Loop"; the red circular patch at upper left is the Rosette Nebula. The photograph is a 60-minute exposure by Chris Schur, who used a 55mm lens at f/2.8, Fuji RH400 film developed as a negative, and a Deep-Sky filter.

Right: This month's $100 winner of the "Best Astrophoto" contest is Vance C. Tyree, who made this 60-minute exposure of the North America Nebula with a 5-inch f/4 apochromatic refractor and hypered Fuji 50 film.

in the evening sky, Mars remains a small object even in a high-magnification eyepiece. Its apparent diameter (7.7″ on the 15th) is too small to reveal much except perhaps a hint of the Red Planet's white south polar cap, shrinking under the tepid rays of the distant Sun.

Don't miss Mars' conjunction with Jupiter, however. At 6h46m UT on the 19th, Mars will overtake Jupiter, passing 31′ north of it — and the pair will be fairly close during the week before and after. At closest approach it will probably take your lowest magnification eyepiece to place the two in the same field of view. (Astrophotographers: this is the perfect event for a series of photos using a 500mm or 1000mm lens.)

Minor Planets

1 Ceres (magnitude 8.5) is moving southeastward in Libra and Scorpius. Its positions:

1st: 15h 24m 24s, −14° 01.2′
10th: 15h 39m 36s, −15° 07.0′
20th: 15h 56m 24s, −16° 13.1′
30th: 16h 13m 03s, −17° 11.8′

At mid-month Ceres rises shortly before morning twilight begins.

2 Pallas (9.4) is moving eastward in eastern Virgo. Its positions:

1st: 14h 11m 43s, −0° 37.4′
10th: 14h 27m 06s, −0° 37.3′
20th: 14h 43m 43s, −0° 25.2′
30th: 14h 59m 45s, 0° 00.7′

Pallas rises around 3:30 a.m. local time on the 15th.

3 Juno (11.0) is moving eastward in Serpens Cauda and Scutum. Its positions:

1st: 18h 01m 13s, −13° 44.5′
10th: 18h 14m 40s, −13° 52.9′
20th: 18h 29m 38s, −13° 55.0′
30th: 18h 44m 58s, −13° 49.3′

Juno sets around 6:30 p.m. local time on the 15th.

4 Vesta (7.8) lies near the borders of Cetus, Aquarius, and Pisces. Its positions:

1st: 0h 26m 59s, −7° 02.7′
10th: 0h 30m 00s, −6° 05.5′
20th: 0h 35m 27s, −4° 51.0′
30th: 0h 42m 48s, −3° 27.6′

Vesta sets around midnight on the 15th.

22 Kalliope (10.5) is at opposition on December 3 and is moving retrograde in Taurus, north of the Hyades and east of the Pleiades. Its positions:

1st: 4h 41m 53s, 23° 56.7′
10th: 4h 32m 33s, 24° 27.7′
20th: 4h 22m 55s, 24° 57.4′
30th: 4h 15m 07s, 25° 23.5′

Kalliope is visible all night.

To locate a minor planet, plot its dated positions (given for 0h UT) lightly in pencil on a good star map (*Sky Atlas 2000.0*, for example) and sketch a smooth curve linking the points. Then observe the starfield at low magnification and photograph or plot by hand what you see. Check the field a night or two later; the "star" that moved is it. (All minor planet coordinates are for the epoch 2000.0.)

Jupiter

Apart from its conjunction with Mars, Jupiter is a fine telescopic target in itself. Although it is about 10″ smaller than it was at opposition in September, Jupiter is high enough in the sky that you can use a 200x eyepiece or more when the seeing is good. Don't necessarily look for a night that is clear and transparent, though. Instead, check what the stars are doing. If they are twinkling madly, forget it and go look at nebulae or galaxies with moderate to low power. The seeing then is too poor to let you use your scope's resolving power to the fullest.

Rather than dark transparent nights, however, look for one that's perhaps a little hazy but which has *really* steady star images. That's the kind of night — ideal for high-magnification viewing — that you want for observing the planets and the Moon. And if the seeing is good, plan to stay out late and make the most of it. You may not get a good night like that again for quite a while.

Saturn

Saturn is in conjunction with the Sun on December 4 but will be visible low in the southeastern sky before sunrise by the end of the month. Its low elevation, however, will produce bad telescopic seeing; your views of the ringed planet will be better in January.

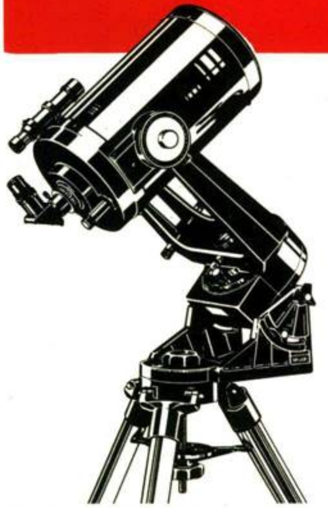
Uranus

Uranus is in conjunction with the Sun on December 14 and it is out of view all month.

Neptune

Neptune is in conjunction (on the 27th) and is also out of view.

MEADE SPECIALS



Meade 2080 LX-3 $1699
With MCSO. Superior 8" Schmidt-Cassegrain design with multi-coated silver optics, AC/DC quartz drive, 8x50mm illuminated polar reticle finderscope, Research Grade eyepiece, Erfle eyepiece, piggyback camera mount, wedge, field tripod, lifetime warranty, and more.

2080 LX-3 Accessories

#36 Remote Control Box	$99
#38 Declination Motor	$99
Both only	$179

Meade 2080 GEM $929
8" Schmidt-Cassegrain with German-type equatorial mount incorporates worm-gear controls on both axes. Optional computer control system.

2080 GEM with MCSO $1029
Multi-coated silver optics group yields increase in light transmission. German equatorial mount.

NEW LOW PRICE!
Meade 2120 LX-3 $2595
With MCSO. 10" system is 56% brighter than an 8" system, for improved viewing and astrophotography capabilities. Includes equatorial wedge and field tripod, plus all the features of the above 2080 LX-3.

Meade 2045 $579
Compact 4" Schmidt-Cassegrain telescope, spotting, scope, and 1000mm lens all-in-one! Includes clock drive, metal-clad case, 5x24mm finder, 40x and 111x eyepieces, coated optics, tabletop tripod, lifetime warranty, & more.

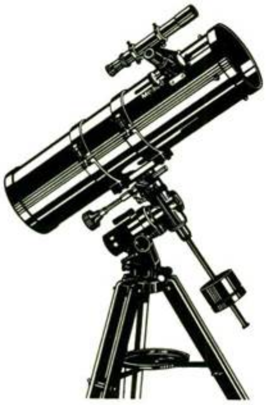
Meade 2045 LX-3 $779
4" Schmidt-Cassegrain with quartz drive, dual motor system, AC/DC operation. State-of-the art electronics for sharp, brilliant images.

Meade DS 16A $1849
16" Deep space reflector for serious space viewing and astrophotography. Shipping truck freight collect.

Meade DS 10A $995
10" Deep space f/4.5 reflector. Includes 25mm eyepiece, focuser, pedestal mount, setting circles, worm gear motor drive, and lifetime warranty.

Meade 622 $429
6" f/3.6 Cometracker Schmidt-Newtonian. Super-fast wide field for observing and astrophotography. Images are sharp, bright, and coma-free to the field edge.

Meade 6600 Special! $599
Compact 6" Newtonian reflector. Includes two eyepieces, 6x30mm finder, professional series equatorial mount with slow motion controls, metal tube assembly, dust cover, altitude & azimuth fine adjustments, setting circles, and lifetime warranty.



Meade 8800 Special $799
8" f/4.5 Newtonian reflector for incredible deep space viewing and astrophotography. Includes features and accessories described above under 6600.

Meade 440 $1149
4" German equatorial refracting telescope complete with 40x and 111x MA eyepieces.

Meade 291 $239
2.4" equatorial refractor is excellent for lunar and planetary viewing. Includes 36x & 100x eyepieces.

Meade 295 $319
2.4" refractor with German equatorial mount for maximum stability. Includes 36x & 100x eyepieces.

Meade 310 $389
3.1" altazimuth refractor. Excellent quality large diameter refractor at an affordable price.

Meade 107D $399
1000mm f/10 compact 4" Mangin Cassegrain spotting scope and telephoto lens with coated optics. Includes: case, 5x-24 finder, 40x & 111x eyepieces, tripod adapter, micrometer focusing, and lifetime warranty.

Meade 97D $329
3.5" 1000mm f/11 Maksutov-Cassegrain. Ideal spotting scope/telephoto lens combination.

Meade 97E $379
3.5" f/11 Maksutov-Cassegrain with 45° erect image diagonal prism and 5x21 erect image viewfinder.

Meade 97ER $409
3.5" f/11 Maksutov-Cassegrain with 45° diagonal prism plus rubber coating for maximum durability and weather resistance.

Meade 11x80 Rubber Armoured Binoculars $275
4.5° field of view. Outstanding performance and durability.

MEADE ACCESSORIES

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6.4mm	$89
9.7mm	$89
12.4mm	$89
15mm	$89
20mm	$89
26mm	$89
32mm	$115
40mm	$115
56mm/2"	$199

Meade Super Wide Angle Eyepieces

13.8	$139
18	$149
24.5	$169
32mm/2"	$249
40mm/2"	$319

Meade Ultra Wide Angle Eyepieces

4.7	$169
6.7	$199
8.8 1.25/2"	$239
14 1.25/2"	$279

Meade 1.25" Barlow Lenses

2x	$89
2.8x	$89

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Meade List Prices on all Barlows, Eyepieces, and Piggyback brackets not listed in this ad.

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Bausch & Lomb 8001 $1295
National Camera Exchange is pleased to premier the system that's light years ahead of its time! 8" Schmidt-Cassegrain features an enhanced aluminum primary mirror, silver secondary mirror, and magnesium flouride coated corrected plate. The oversized primary mirror offers full field illumination. Research grade dual motor clock drive, with continuous feed gear train for uniform power transmission, provides precise tracking both visually and photographically. A comprehensive system of optional accessories allows you to add as your interests grow. Includes limited lifetime warranty, wedge, and tripod.

Bausch & Lomb 4000 Observatory $449
4" Schmidt-Cassegrain compact telescope. With electric clock drive, case, two eyepieces, 1200mm f/11 coated optics, tabletop tripod, lifetime warranty, and more. $695 list.

Bausch & Lomb 4000 Pro $499
Same as 4000 above, but with enhanced aluminum coated primary mirror, silver coated secondary mirror, and multi-coated corrector plate.

Bausch & Lomb 4000 Pro Kit $529
4000 Pro with Barlow and 35mm camera adapter.

Bausch & Lomb 4000 Spotting Scope $349

Bausch & Lomb Discoverer $249
15x60 with FREE case, camera adapter, and T mount.

Bausch & Lomb Accessories

Solar Filter 4000	$109
Wedge for 4000	$70
Polar Alignment Kit	$28
Camera Mount	$24
Nebula Filter	$77
Eyepiece Projection Tube	$24
8000 Piggyback Mount	$37
Porro Prism	$45
Drive Corrector	$199
Focal Reducer f5	$42
Focal Reducer f7.5	$42
4000 Piggyback Mount	$24
8.4-21 Zoom O/R eyepiece	$89
16.3mm Erfle	$53
32mm Plossl	$53
9mm Symmetrical	$33

Bausch & Lomb Pro Eyepieces $69
Pro 35mm Plossl
Pro 26mm Plossl
Pro 17mm Plossl
Pro 10mm Plossl

Beginning Astrophotography Kit $59
Includes piggyback for 4000, eyepiece adapter, eyepiece projection tube, Robert T. Little's Astrophotography book, camera mount.

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Compact roof prism design, camouflaged rubber armour, with case.

Swift 7x50 Storm King $229
Waterproof binocular with brilliant wide field image. Case included.

Swift 11x80 Observer Binoculars $199
Exceptional astro binocular. Includes tripod adapter and case.

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Outstanding magnification at a low price. With tripod adapter and case.

Tele Vue Eyepieces
Simply the best.

55mm Plossl	$175
40mm Plossl	$100
32mm Plossl	$100
26mm Plossl	$89
21mm Plossl	$89
17mm Plossl	$89
13mm Plossl	$89
10.5mm Plossl	$89
7.4mm Plossl	$89
1.8x Barlow	$89
2.5x Barlow	$89
13mm Nagler	$235
11mm Nagler	$225
9mm Nagler	$210
7mm Nagler	$180
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8" Schmidt-Cassegrain provides both visual and astrophotographic excellence. Includes wedge and tripod. Quartz dual axis drive corrector $229 Limited quantities. With Starbright.

Celestron C-11 with Starbright $3395
11" 2800mm Schmidt-Cassegrain captures deep sky nebulae color with superior resolution, in a portable instrument. C-11 wedge and tripod . . . $879

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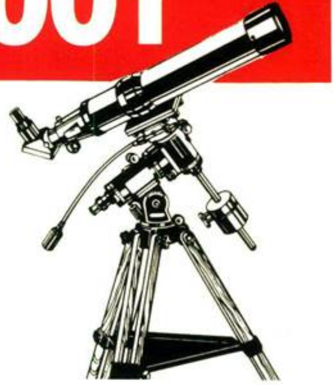

Tele Vue Renaissance Telescope $1295
4" f/5.5 refractor with 4-element multi-coated objective. 5° Rich Field capability and high resolution. Old world craft with modern technology. Comes with one eyepiece. (Choose 7.4mm, 10.5mm, 13mm, 17mm, 21mm, or 26mm.)

Tele Vue Renaissance Accessories

Systems mount	$395
Wood Tripod	$280
Aluminum Tripod	$175
Adapter Plate	$32
Extra Balance Weight	$20
Polar Axis Telescope	$76
Illuminator	$24
Motor Drive CXD-1	$176
Std. Equatorial Mount	$339
2" Star Diagonal	$150
Schmidt-Cassegrain adapter	$25
2" to 1¼" adapter	$25
Eyepiece Projection Tube	$76

Save an Additional 5% off any Tele Vue Accessory with Purchase of Telescope.

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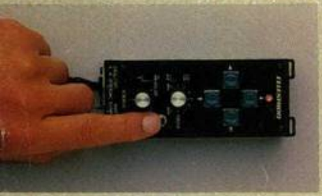

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